Lower Clark Fork River Subbasin Assessment and Total Maximum Daily Loads

DRAFT

Department of Environmental Quality

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Acknowledgments

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Abbreviations, Acronyms, and Symbols

§303(d) Refers to section 303 subsection (d) of the Clean Water Act, or a list of impaired water bodies required by this section

µ micro, one-one thousandth

§ Section (usually a section of federal or state rules or statutes)

ADB assessment database

AU assessment unit

AWS agricultural water supply

BAG Basin Advisory Group

BLM United States Bureau of Land Management

BMP best management practice

BOD biochemical oxygen demand

BOR United States Bureau of Reclamation

Btu British thermal unit

BURP Beneficial Use Reconnaissance Program

C Celsius

CFR Code of Federal Regulations (refers to citations in the federal administrative rules)

cfs cubic feet per second

cm centimeters

CWA Clean Water Act

CWAL cold water aquatic life

CWE cumulative watershed effects

DEQ Department of Environmental Quality

DO dissolved oxygen

DOI U.S. Department of the Interior

DWS domestic water supply

EMAP Environmental Monitoring and Assessment Program

EPA United States Environmental Protection Agency

ESA Endangered Species Act

F Fahrenheit

FPA Idaho Forest Practices Act

FWS U.S. Fish and Wildlife Service

GIS Geographical Information Systems

HUC Hydrologic Unit Code

I.C. Idaho Code

IDAPA Refers to citations of Idaho administrative rules

IDFG Idaho Department of Fish and Game

IDL Idaho Department of Lands

IDWR Idaho Department of Water Resources

INFISH the federal Inland Native Fish Strategy

IRIS Integrated Risk Information System

km kilometer

km^2 square kilometer

LA load allocation

LC load capacity

m meter

m^3 cubic meter

mi mile

mi^2 square miles

MBI Macroinvertebrate Biotic Index

MGD million gallons per day

mg/L milligrams per liter

mm millimeter

MOS margin of safety

MWMT maximum weekly maximum temperature

n.a. not applicable

NA not assessed

NB natural background

nd no data (data not available)

NFS not fully supporting

NPDES National Pollutant Discharge Elimination System

NRCS Natural Resources Conservation Service

NTU nephelometric turbidity unit

ORV off-road vehicle

ORW Outstanding Resource Water

PACFISH the federal Pacific Anadromous Fish Strategy

PCR primary contact recreation

PFC proper functioning condition

ppm part(s) per million

QA quality assurance

QC quality control

RBP rapid bioassessment protocol

RDI DEQ's River Diatom Index

RFI DEQ's River Fish Index

RHCA riparian habitat conservation area

RMI DEQ's River Macroinvertebrate Index

RPI DEQ's River Physiochemical Index

SBA subbasin assessment

SCR secondary contact recreation

SFI DEQ's Stream Fish Index

SHI DEQ's Stream Habitat Index

SMI DEQ's Stream Macroinvertebrate Index

SRP soluble reactive phosphorus

SS salmonid spawning

SSOC stream segment of concern

STATSGO State Soil Geographic Database

TDG total dissolved gas

TDS total dissolved solids

T&E threatened and/or endangered species

TIN total inorganic nitrogen

TKN total Kjeldahl nitrogen

TMDL total maximum daily load

TP total phosphorus

TS total solids

TSS total suspended solids

t/y tons per year

U.S. United States

U.S.C. United States Code

USDA United States Department of Agriculture

USDI United States Department of the Interior

USFS United States Forest Service

USGS United States Geological Survey

WAG Watershed Advisory Group

WBAG *Water Body Assessment Guidance*

WBID water body identification number

WET whole effluence toxicity

WLA wasteload allocation

WQLS water quality limited segment

WQMP water quality management plan

WQRP water quality restoration plan

WQS water quality standard

Executive Summary

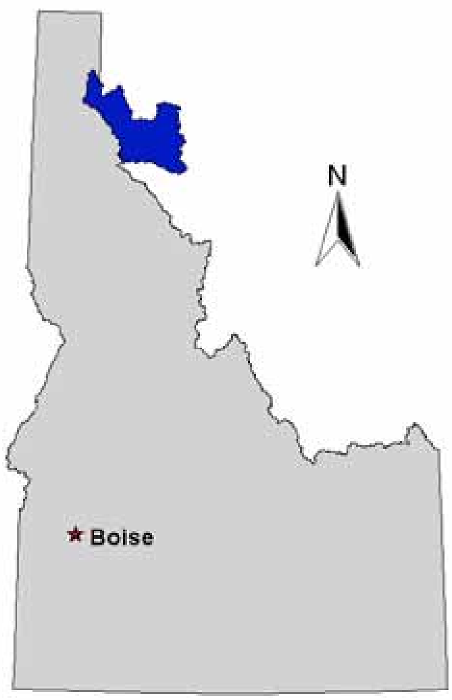
The federal Clean Water Act (CWA) requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters. States and tribes, pursuant to Section 303 of the CWA, are to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the nation's waters whenever possible. Section 303(d) of the CWA establishes requirements for states and tribes to identify and prioritize water bodies that are water quality limited (i.e., water bodies that do not meet water quality standards). States and tribes must periodically publish a priority list (a "§303(d) list") of impaired waters. Currently this list must be published every two years. For waters identified on this list, states and tribes must develop a total maximum daily load (TMDL) for the pollutants, set at a level to achieve water quality standards.

This document addresses the water bodies in the Lower Clark Fork River Subbasin that have been placed on Idaho's current §303(d) list.

This subbasin assessment (SBA) and TMDL analysis have been developed to comply with Idaho's TMDL schedule. The assessment describes the physical, biological, and cultural setting; water quality status; pollutant sources; and recent pollution control actions in the Lower Clark Fork River Subbasin, located in northeast Idaho.

The first part of this document, the SBA, is an important first step in leading to the TMDL. The starting point for this assessment was Idaho's current §303(d) list of water quality limited water bodies. Twenty-four segments in ten waterbodies in the Lower Clark Fork River Subbasin are listed as water quality limited. The SBA examines the current status of §303(d) water quality limited waters and defines the extent of impairment and causes of water quality limitation throughout the Subbasin. The TMDL analysis quantifies pollutant sources and allocates responsibility for load reductions needed to return listed waters to a condition of meeting water quality standards.

Subbasin at a Glance



Lower Clark Fork River Subbasin

Hydrologic Unit Code: 17010213

Listed Water Quality Limited Streams: Cascade Creek, Clark Fork River, Dry Creek, Twin Creek, East Fork Creek, Johnson Creek, Lightning Creek, Morris Creek, Porcupine Creek, Rattle Creek, Savage Creek, and Wellington Creek.

Beneficial Uses Affected: Cold water aquatic life, salmonid spawning, primary and secondary contact recreation, domestic water supply, special resource water.

Pollutants of Concern: Sediment, temperature, metals, total dissolved gas, unknown biological impairment.

Uses: Forestry, agriculture, rural residential, recreation.

Figure A. Location of the Lower Clark Fork River Subbasin.

Primarily located in the state of Montana, the Lower Clark Fork River subbasin, hydrologic unit code 17010213, covers 2,335 mi^2. This document addresses the lower most 247 mi^2 acres of the subbasin located in northern Idaho. The headwaters of the Clark Fork River originate in northwest Montana in the Silver Bow mountains, and by the time it reaches its terminus in Pend Oreille Lake, the river has drained over 22,000 square miles.

The Lower Clark Fork River provides over 92% of the inflow to Lake Pend Oreille, the recreational and economic hub of the area. The Lightning Creek watershed, its largest tributary in Idaho, harbors a regionally significant bull trout population and supports many other native fish. There are many relatively pristine and functioning areas in the watershed. Water quality is generally considered good and worthy of protection and restoration, where necessary, with many restoration projects underway to reduce legacy impacts of forest roads and other activities. With approximately 75 % of the Subbasin in public ownership, there is a diversity of recreational opportunities, as well as substantial wildlife habitat. Both the mainstem Lower Clark Fork River and Lightning Creek are designated Special Resource Waters by the state of Idaho. Special protections of beneficial uses in these waters are given in recognition of their outstanding or unique characteristics. Primarily, this designation prohibits additional point source pollution permits to protect current beneficial uses.

However, the mainstem of the Lower Clark Fork River exceeds several of the State of Idaho's water quality standards, as do many of its tributaries. Within the Idaho portion of the watershed, there are twenty-four water quality limited segments on the 2002 Idaho §303(d) list that will be addressed in this document. These segments represent portions of the Lower Clark Fork River Subbasin in Idaho and its tributaries.

Intensive mining around the headwaters of the Clark Fork left residues of heavy metals behind, which still pose a risk to water quality throughout the basin. The Cabinet Gorge hydropower project is located in Idaho just downstream for the Montana/Idaho border and has been operating on the Lower Clark Fork River since 1952. With additional hydropower facilities upstream, the flows and habitat conditions for native aquatic species in the entire Clark Fork River system have been extensively altered by hydropower development. After a multi-year effort, in 2000, as a condition of obtaining a federal license to operate the hydropower facility, a collaborative group of stakeholders and resource agencies partnered with Avista, the operator of the Cabinet Gorge Dam, to direct mitigation measures aimed at restoring water quality and native fish populations in the entire Lower Clark Fork River Subbasin.

In addition to flow and habitat alterations in the system, thick glacial outwash sediments in steep drainages combined with timber harvest and road creation have created potential sediment problems in several of the tributaries to the Clark Fork River.

Idaho DEQ’s Beneficial Use Reconnaissance Program’s Stream (BURP) Macroinvertebrate Index scores, other existing stream surveys, and water quality samples were used to determine whether designated and existing beneficial uses of streams are being supported. Existing beneficial uses include cold water aquatic life, salmonid spawning, primary contact recreation, domestic water supply, and special resource waters (waters that are recognized as needing special protection to preserve outstanding or unique characteristics or to maintain a current beneficial use).

Pollutants of concern identified during the assessment for this process are sediment, temperature, metals, and total dissolved gas. Several segments were found to be biologically impaired, though the pollutants were unknown at the time of listing. The TMDL process helped identify the pollutants causing impairment in these systems and suggests changes to the 303(d) list to reflect these determinations.

Figure B shows the Idaho 2002 §303(d) listed segments in the Lower Clark Fork River Subbasin.

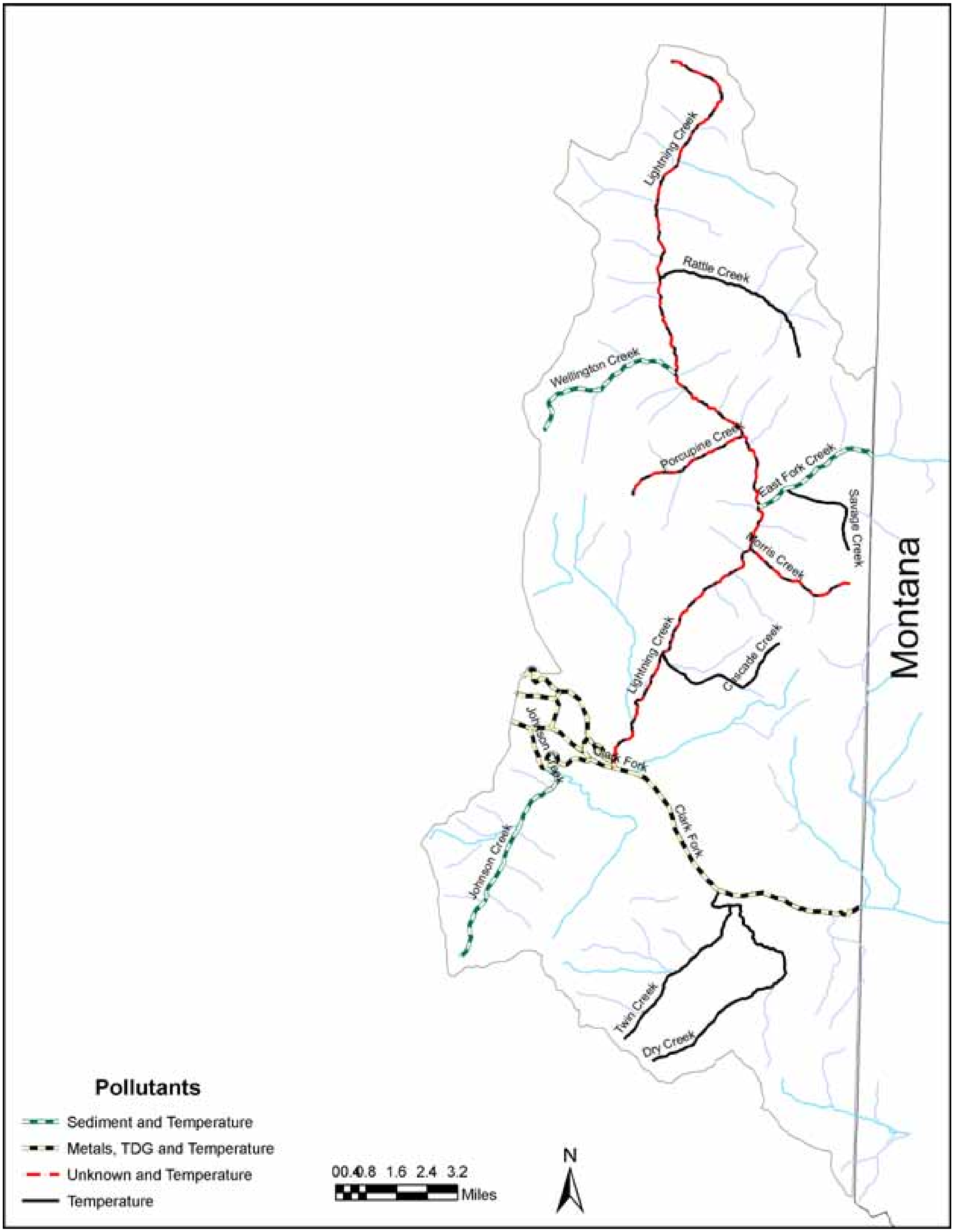


Figure B. Lower Clark Fork River Subbasin Waterbodies and 2002 303(d) Listed Streams.

A total maximum daily load (TMDL) has been developed for each stream determined to be not fully supporting beneficial uses in accordance with state of Idaho Water Quality Standards. Water Quality Standards are in place to protect and maintain water quality in Idaho's rivers. Development and implementation of TMDLs is an important step toward ensuring all Idaho's waters support their designated beneficial uses. The total maximum daily loads included in this document address in-stream sediment, metal, and temperature reduction goals to maintain or restore cold water aquatic life and salmonid spawning. The total maximum daily loads help quantify needed improvements and suggest management actions to address water quality improvement measures and timelines.

Key Findings

Table A. Streams and pollutants for which TMDLs were developed. [To be updated with final list based on sediment model.]

Stream	Pollutant(s)
Clark Fork River	Metals, Temperature, TDG
Cascade Creek	Temperature
Twin Creek	Temperature
East Fork Creek	Sediment, Temperature
Johnson Creek	Sediment, Temperature
Lightning Creek (including Morris and Porcupine Creeks)	Sediment, Temperature
Rattle Creek	Temperature
Savage Creek	Temperature
Wellington Creek	Sediment, Temperature

Table B. Summary of assessment outcomes. [To be updated when TMDLs complete.]

Water Body Segment	Assessment Unit	Pollutant(s)	TMDL(s) Completed	Recommended Changes to Integrated Report	Justification
Dry Creek		Temperature	no	Move to unassessed waterbody	No data available. Previously listed due to data that is actually attributed to Twin Creek. Stream is dry majority of year.

1. Subbasin Assessment – Watershed Characterization

The federal Clean Water Act (CWA) requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters. States and tribes, pursuant to Section 303 of the CWA, are to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the nation's waters whenever possible. Section 303(d) of the CWA establishes requirements for states and tribes to identify and prioritize water bodies that are water quality limited (i.e., water bodies that do not meet water quality standards). States and tribes must periodically publish a priority list (a "§303(d) list") of impaired waters. Currently this list must be published every two years. For waters identified on this list, states and tribes must develop a total maximum daily load (TMDL) for the pollutants, set at a level to achieve water quality standards. (In common usage, a TMDL also refers to the written document that contains the statement of loads and supporting analyses, often incorporating TMDLs for several water bodies and/or pollutants within a given watershed.)

This document addresses the water bodies in the Lower Clark Fork River Subbasin that have been placed on Idaho's current §303(d) list.

The overall purpose of the subbasin assessment (SBA) and TMDL is to characterize and document pollutant loads within the Lower Clark Fork River Subbasin. The first portion of this document, the SBA, is partitioned into four major sections: watershed characterization, water quality concerns and status, pollutant source inventory, and a summary of past and present pollution control efforts (Sections 1 – 4). This information will then be used to develop a TMDL for each pollutant of concern for the Lower Clark Fork River Subbasin (Section 5).

1.1 Introduction

In 1972, Congress passed the Federal Water Pollution Control Act, more commonly called the Clean Water Act. The goal of this act was to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (Water Environment Federation 1987, p. 9). The act and the programs it has generated have changed over the years, as experience and perceptions of water quality have changed.

The CWA has been amended 15 times, most significantly in 1977, 1981, and 1987. One of the goals of the 1977 amendment was protecting and managing waters to insure "swimmable and fishable" conditions. This goal, along with a 1972 goal to restore and maintain chemical, physical, and biological integrity, relates water quality with more than just chemistry.

Background

The federal government, through the U.S. Environmental Protection Agency (EPA), assumed the dominant role in defining and directing water pollution control programs across the country. The Department of Environmental Quality (DEQ) implements the CWA in Idaho, while the EPA oversees Idaho and certifies the fulfillment of CWA requirements and responsibilities.

Section 303 of the CWA requires DEQ to adopt water quality standards and to review those standards every three years (EPA must approve Idaho's water quality standards). Additionally, DEQ must monitor waters to identify those not meeting water quality standards. For those waters not meeting standards, DEQ must establish a TMDL for each pollutant impairing the waters. Further, the agency must set appropriate controls to restore water quality and allow the water bodies to meet their designated uses.

These requirements result in a list of impaired waters, called the "§303(d) list." This list describes water bodies not meeting water quality standards. Waters identified on this list require further analysis. A SBA and TMDL provide a summary of the water quality status and allowable TMDL for water bodies on the §303(d) list. *Lower Clark Fork River Subbasin Assessment and Total Maximum Daily Loads* provides this summary for the currently listed waters in the Lower Clark Fork River Subbasin.

The SBA section of this document (Sections 1 – 4) includes an evaluation and summary of the current water quality status, pollutant sources, and control actions in the Lower Clark Fork River Subbasin to date. While this assessment is not a requirement of the TMDL, DEQ performs the assessment to ensure impairment listings are up to date and accurate. The TMDL is a plan to improve water quality by limiting pollutant loads. Specifically, a TMDL is an estimation of the maximum pollutant amount that can be present in a water body and still allow that water body to meet water quality standards (Water quality planning and management, 40 CFR Part 130). Consequently, a TMDL is water body- and pollutant-specific. The TMDL also allocates allowable discharges of individual pollutants among the various sources discharging the pollutant.

Some conditions that impair water quality do not receive TMDLs. The EPA considers certain unnatural conditions, such as flow alteration, human-caused lack of flow, or habitat alteration, that are not the result of a specific pollutant discharge, as "pollution." However, TMDLs are not required for water bodies impaired by pollution, if the pollution is not caused by specific pollutants. A TMDL is only required when a pollutant, like sediment or temperature, can be identified and in some way quantified.

Idaho's Role

Idaho adopts water quality standards to protect public health and welfare, enhance the quality of water, and protect biological integrity. A water quality standard defines the goals of a water body by designating the use or uses for the water, setting criteria necessary to protect those uses, and preventing degradation of water quality through antidegradation provisions.

The state may assign or designate beneficial uses for particular Idaho water bodies to support. These beneficial uses are identified in the Idaho water quality standards and include the following:

- Aquatic life support–cold water, seasonal cold water, warm water, salmonid spawning, modified
- Contact recreation–primary (swimming), secondary (boating)
- Water supply–domestic, agricultural, industrial
- Wildlife habitats
- Aesthetics

The Idaho legislature designates uses for water bodies. Industrial water supply, wildlife habitats, and aesthetics are designated beneficial uses for all water bodies in the state. If a water body is unclassified, then cold water and primary contact recreation are used as additional default designated uses when water bodies are assessed.

A SBA entails analyzing and integrating multiple types of water body data, such as biological, physical/chemical, and landscape data to address several objectives:

- Determine the degree of designated beneficial use support of the water body (i.e., attaining or not attaining water quality standards).
- Determine the degree of achievement of biological integrity.
- Compile descriptive information about the water body, particularly the identity and location of pollutant sources.
- Determine the causes and extent of the impairment when water bodies are not attaining water quality standards.

Compliance with Idaho Code §39-3611(8)

The development of the Lower Clark Fork River Subbasin Assessment and TMDL included extensive public participation by the Watershed Advisory Group (WAG) and other interested parties in the Basin. All meetings were open to the public and advertised at least one-week prior to the meeting, in addition to being noted on the DEQ public meeting calendar on the internet.

2003-2004: DEQ worked with Designated Management Agencies to gather relevant information for the TMDLs. Public notice was given, and two public meetings were held in Spring 2004 to introduce the public to the TMDL process and to form a WAG. Due to staff changes, between May 2004 and May 2005 there were limited resources to devote to this TMDL.

In June 2005, DEQ work on the TMDL began again.

In August 2005, DEQ sent a letter and survey to all participants in the original meetings, designated management agencies and interested parties in the region. Follow-up phone calls were made to individuals who had expressed interest in joining the WAG in 2004.

In September 2005, the first meeting to re-initiate the WAG and invite new participation concentrating on identifying stakeholders as outlined in Idaho Code. Participants were given a draft copy of the Subbasin Assessment, background on DEQ's responsibility under HB145 and a draft schedule for completion. Public notice was given for each meeting in local newspaper and radio public calendars. An e-mail list of interested parties was created for notification of future meetings.

In October 2005, follow-up invitations were sent to parties who had expressed interest in 2004, but did not attend the meeting or respond to the September mailing. Public notice on community calendars and at the DEQ office was given for the meeting. Participants reviewed beneficial use designations in the watershed and water quality information to date, and comment was taken on the draft Subbasin Assessment.

In November 2005, a mailing went to approximately 80 individuals identified by the WAG as being potential interested parties. The mailing included a meeting announcement for the December 2005 meeting and information on a web page dedicated to sharing information from the meetings. Public notice on community calendars was given, and a small newspaper article announcing the December meeting was published in the Bonner County Bee and the Coeur d'Alene Press.

In December 2005, a WAG meeting was held to discuss existing water quality information in the mainstem Clark Fork River and the Lightning Creek drainage and input on TMDL development was provided by the WAG.

In January 2006, a WAG meeting was held to discuss draft temperature and metals TMDLs. Preliminary load calculations for each pollutant were presented, and hard copies of these draft TMDLs were provided to the WAG for review.

In February 2006, a WAG meeting was held to discuss the strategy for addressing sediment TMDLs, with a focus on the Lightning Creek drainages. WAG feedback on specific parameters of the proposed sediment model was taken. In addition, water quality information on Cascade Creek and Twin Creek was discussed with local landowners familiar with those areas.

In April 2006, a WAG meeting was held to discuss preliminary results and TMDL calculations for sediment impaired streams in the subbasin. Proposed sediment reduction targets were presented, based on reference streams recommended by the WAG at the February meeting. An updated draft of the SBA was provided to the WAG and comments and changes to the draft temperature TMDLs were discussed with the WAG.

[Describe additional WAG meetings and public comment process.]

DEQ has compiled with the WAG consultation requirements set forth in Idaho Code § 39-3611. DEQ has provided the WAG with all available information concerning applicable water quality standards, water quality data, monitoring, assessments, reports, procedures and schedules. Indeed, DEQ worked closely with the WAG in collecting the information for the proposed Waste Load Allocations and in developing the Subbasin Assessment. All presentations and drafts provided at WAG meetings were made available on the DEQ web-site throughout the process.

DEQ utilized the knowledge, expertise, experience and information of the WAG in developing this TMDL. DEQ also provided the WAG with an adequate opportunity to participate in drafting the TMDL and to suggest changes to the document. Subsequent to the development of the original draft SBA proposed in 2005, the WAG and members of the public attending WAG meetings have continued to provide DEQ with input, information and suggestions for the changes through monthly meetings in late 2005 and early 2006.

1.2 Physical and Biological Characteristics

The Clark Fork River originates near Butte, Montana and drains approximately 22,000 square miles in western Montana and northern Idaho, 247 square miles of which comprise the Lower Clark Fork subbasin in northern Idaho. The river drains into the 95,000-acre surface area Lake Pend Oreille, and as the lake's largest tributary, the Clark Fork River contributes approximately 92% of the annual inflow to the lake and most of the annual suspended sediment load.

The following section outlines climate data for the entire Subbasin, as well as the hydrography and geology of the area. General trends in fish populations and influences to their survival are presented. Finally, specific stream type information for individual streams is presented. This information serves as background for understanding current and potential water quality impairment.

Climate

Monthly climate data has been collected near the Cabinet Gorge Dam, Idaho by the Western Regional Climate Center since 1956. (Weather station locations are shown in Figure X.) The average monthly temperature over the 49-year period of record (1956-2005) ranges from a high of 82.6° F in July to a low of 21.2° F in January. The extreme maximum of all daily maximum temperatures over the period of record was 105° F in early August 1961. The extreme minimum of all daily minimum temperatures over the period of record was minus 28° F in late December 1968.

At the Cabinet Gorge station (2260 feet elevation), the average annual precipitation over the period of record was 32.33 inches with November being the wettest month and July the driest. Most precipitation is in the form of snow, with the highest snowfall levels generally occurring in January. Due to the mountainous terrain, precipitation varies noticeably among some of the watersheds in the subbasin.

Particularly at higher elevations, average snow pack in the Clark Fork Basin can be significant. For example, the Bear Mountain snow telemetry station at an elevation of 5400 feet, near the headwaters of Rattle Creek, reported a maximum of 82 inches of precipitation in form of snow for the 2002 water year. Rain-on-snow events and spring runoff have the potential of moving tremendous amounts of bedload, especially in the Lightning Creek drainage.

Subbasin Characteristics

The Lower Clark Fork subbasin includes 180 miles of perennial streams. The river itself flows from east to west, with its main tributary, Lightning Creek, entering from the north. Steam channels in the basin tend to be Rosgen A or B types, with gradients ranging from .05% to 7%.

Hydrography

River flow information is collected at two stations in the subbasin. USGS gaging stations are located just below the Cabinet Gorge dam and at the mouth of Lightning Creek near the City of Clark Fork. There is a NRCS weather station at Bear Mountain in the Lightning Creek drainage, and a National Weather Service station at the Cabinet Gorge dam. Gaging station locations are shown in Figure X.

The Clark Fork River flows into four reservoirs and passes over four power-generating dams before entering the northeast portion of Lake Pend Oreille. Three of the reservoirs and dams are located entirely in Montana, while the final dam (Avista's Cabinet Gorge facility) is located just downstream from the Montana/Idaho border 10 miles before the river enters Lake Pend Oreille. Primarily in Montana, the Cabinet Gorge reservoir has a storage capacity of 105,000 acre feet at full pool, with a pool that backs up to the Noxon Rapids dam. It is licensed to produce 231 megawatts of power. The minimum flow over the dam is 5,000 cubic feet per second[1], however, flows are generally much higher, ranging from minimum flow to over 50,000 cfs during peak run-off.

The entire subbasin is highly influenced by rain-on-snow events, with a portion of most subwatersheds in the primary rain-on-snow zone between 3000-4500 feet (915-1372 m). During warm years, the rain-on-snow zone can extend to elevations as high as 7000 feet (2,134 m) (cited in PWA 2004).

Peak flows can be extreme, and will move tremendous amounts of bedload through the system. For example, Table X summarizes peak flow activity in the Lightning Creek drainage. Compared to peak flows of 2,000 to 6,000 cfs, the average mean daily flow recorded at the Lightning Creek station is about 400 cfs. The system has a long history of flood and associated mass wasting events that are frequently associated with rain-on-snow events. For a more detailed summary of historic flooding and climate data for the Lightning Creek watershed, see PWA (2004) and Cacek (1989).

[1] The minimum flow for the Cabinet Gorge dam is a license condition, designated in 1999 Settlement Agreement for operation of the Noxon Rapids and Cabinet Gorge dams.

Table X. Peak flows for Lightning Creek USGS gage by water year, 1989-2003. (Reproduced from PWA, 2004)

Water Year	**Date**	**Discharge (m^3/s)**	**Discharge (cfs)**
1989	5/09/1989	81.0*	2,860*
1990	12/05/1989	85.8*	3,030*
1991	6/30/1991	39.6	1,400
1992	4/30/1992	72.2*	2,550*
1993	5/13/1993	92.9*	3,280*
1994	5/09/1994	79	2790
1995	2/20/1995	100.8*	3,560*
1996	2/09/1996	140.8*	4,970*
1997	5/15/1997	115.5*	4,080*
1998	5/27/1998	92.3	3,260
1999	5/25/1999	80.7	2,850
2000	5/22/2000	107.3*	3,790*
2001	4/28/2001	57.5	2,030
2002	4/14/2002	170.2	6,010
2003	5/25/2003	176.2	6,220

*Maximum daily average

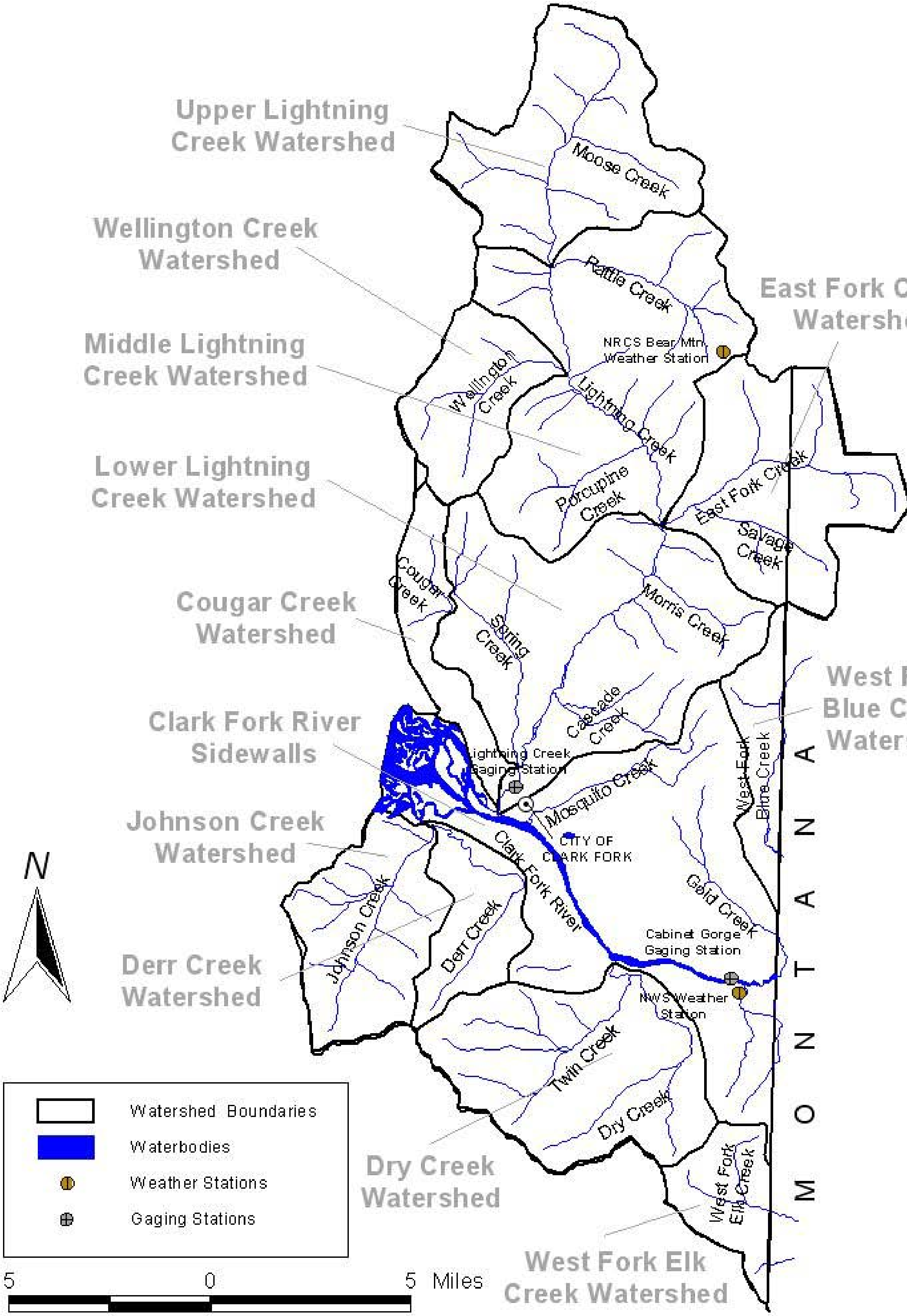


Figure x. Lower Clark Fork River Watersheds, Hydrography, Weather, and Gaging Station

Geology[2]

The geologic parent materials found in the Pend Oreille watershed are the product of millions of years of sedimentation, metamorphosis, uplift, and intrusion. Belt series and Kaniksu batholith are the major underlying bedrock types. The Clark Fork River is primarily located within Belt Series bedrock (Savage 1965). The Belt Series are metamorphic sedimentary deposits comprised partially by the Bitterroot and Cabinet Mountains. These rocks were formed during the Precambrian period when shallow seas inundated northern Idaho. Clay, sand, and silt sediments settled out of brackish waters as the seas retreated. The sediments subsequently metamorphosed, folded, and faulted. The metamorphosed rocks in the basin include argillite, siltite, quartzite, and dolomite (Hoelscher et al. 1993).

The Kaniksu batholith formed about 70 to 80 million years ago when large masses of granite magma rose to the upper part of the Earth's crust. As this mass of granite magma rose, it caused part of the crust to shear off and move easterly, forming a part of the Cabinet Mountains.

The basin was substantially altered by major glacial events in the late Pleistocene period. The present Clark Fork River valley was alternately plugged and scoured by dams of ice and deposited debris that likely served as the primary feature controlling the level and size of glacial Lake Missoula. Lake Missoula once covered much of present day Western Montana. Existing soils in the watershed are derived from the erosion of Precambrian metasediments and granitic batholith, volcanic deposition, glacial outwash, and alluvium. Most land types have ten inches (25.4 cm) or more of surface soils composed of Mt. Mazama volcanic ash, which has very high infiltration rates. The Mt. Mazama ash layer was deposited about 7,000 years ago and is resistant to erosion-causing overland flows.

Watersheds in the Cabinet Mountains, including the Clark Fork subbasin, are prone to rapid runoff events due to the effects of glacial scour. Glacial advances resulted in highly dissected watersheds, shallow soils, and subsoil compaction of glacial tills. Glaciers acted as ice dams and deposited large amount of till in the subbasin. Fine, sandy sediments deposited in the dammed water are known as glacial fluvial deposits. Today these sandy areas appear on mountainside slopes and are very erosive.

Mass erosion is significant in the watershed. Since glacial outwash makes up most of the valley bottoms in the Cabinet Mountains in-channel erosion rates are relatively high. Activities, such as road construction, that intercept groundwater between compacted till layers and the ash layer, can increase surface flow and the potential for mass wasting. On disturbed landscapes, landslides are frequent contributors of sediment due to steep hillslopes and layering of erodible soils over impermeable silts and clays, particularly in the Lightning Creek drainages.

However, when forest conditions are undisturbed within the Pend Oreille basin, surface erosion is generally low to nonexistent on most upland land types.

The geology of an area influences the productivity potential for biological communities in the watershed. Generally, streams on the northern side of Lake Pend Oreille tend to be biologically productive with little fine sediment. These Belt Series streams are more likely to

[2] Much of the geological information in this section was originally reported in the Lake Pend Oreille Key Watershed Bull Trout Problem Assessment (PBTTAT 1998).

have bedload as a limiting factor than the fine sediments. Fish growth is typically slower in the nutrient-poor granitic watersheds flowing from the Cabinet Mountains. Natural waterfalls are found throughout the basin and preclude the use of several tributaries (or portions thereof) by migratory fish.

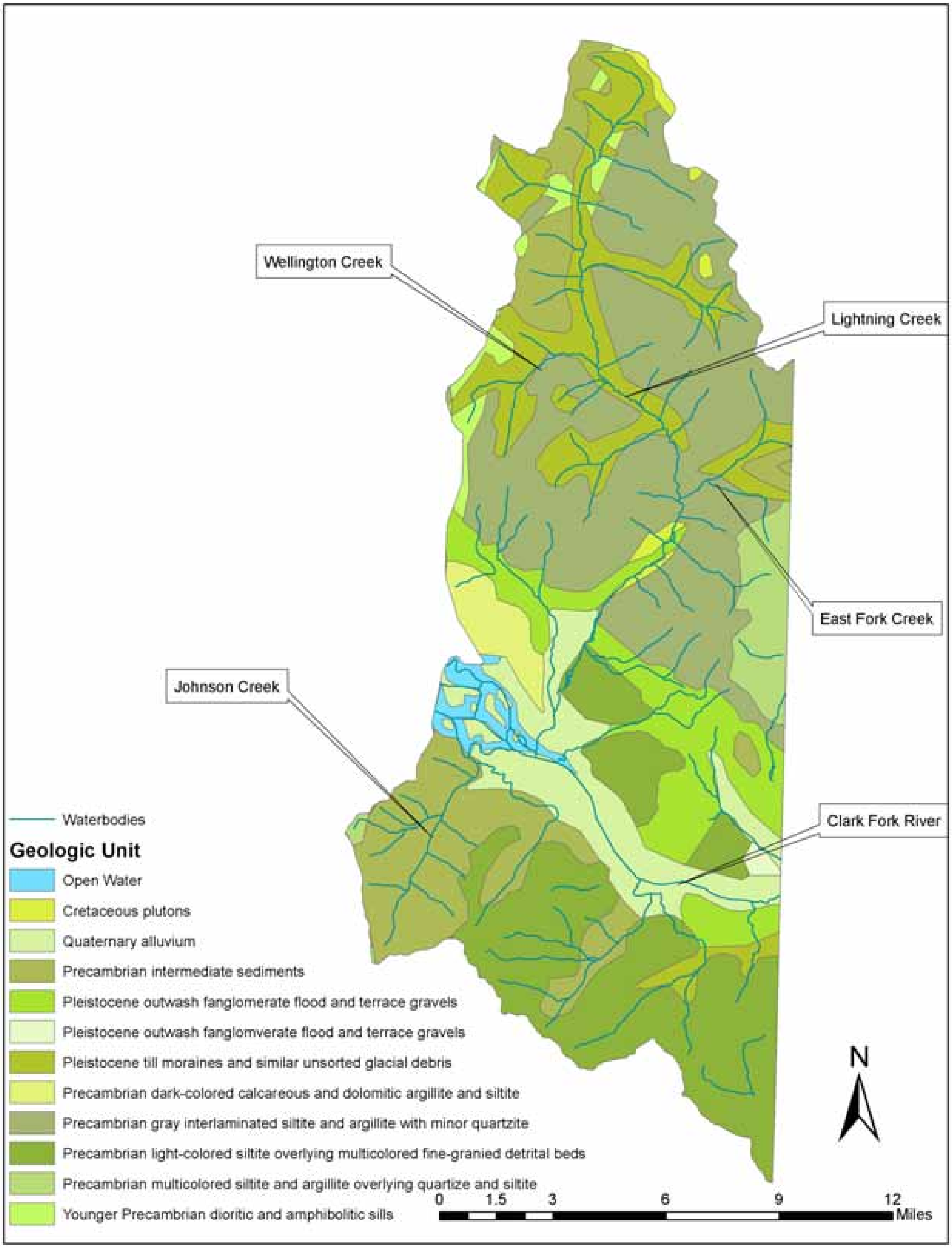


Figure x. Geology of the Lower Clark Fork Subbasin

Topography

The Lower Clark Fork subbasin varies greatly in elevation from lows of 2,060 feet near the Clark Fork River Delta, to a height of 7,009 feet at Scotchman Peak near the center of the subbasin. The subbasin is long and narrow, bounded to the east by the Cabinet Mountains. The river itself runs the width of the subbasin, from east to west, while the river's main tributary, Lightning Creek, enters from the north side of the river. Lightning Creek is north-south oriented and accounts for the upper three quarters of the watershed. Johnson Creek, the river's main southern tributary, originates in the Bitterroot Mountains. The river valley is generally concave in shape, having been formed by glacial activity and the draining of glacial Lake Missoula more than 10,000 years ago. Steep slopes characterize much of the subbasin, with slopes near Scotchman Peak and in the southern portion of the subbasin ranging from 47º to 63º. Slopes in the central and northern part of the subbasin are generally no greater than 16º.

Vegetation

Historic vegetation patterns in the Lower Clark Fork subbasin were largely influenced by wildfire. Early accounts and photographs of the basin indicate that old growth stands of western red cedar (*Thuja plicata*) were common in riparian zones and floodplains. Large cedar stumps can still be found in many riparian areas along streams in the basin. Watershed uplands were more typically dominated by several species in various stages of succession, with age and composition largely dependent on fire cycles and slope aspect.

Early settling of the Clark Fork subbasin was accompanied by forest clearing, agricultural development, logging, introduction of nonnative species, mining, railroad construction, hydroelectric development, and general urbanization. Present day vegetative conditions are a product of these activities and natural and human-caused forest fires.

Forest fires had a profound impact on vegetation within the lower Clark Fork River watershed during the last century. The Montana Department of Fish, Wildlife, and Parks (1984) reports that fires in 1910 burned over 60% of the Cabinet National Forest, part of the present-day Kootenai and Lolo National Forests. That fire burned an estimated 3,000,000 acres (121 km^2) in western Montana and northern Idaho. The most severely burned areas were reportedly on the north and south slopes of the Bitterroot Mountains (Guth and Cohen1991, Pratt and Houston 1993) which form the west-southwest flank of the Clark Fork River valley. However, fire ecologists speculate that riparian areas along the river may have escaped the fire (MDFWP 1984).

Low elevation riparian zones near tributary mouths include areas with and without tree canopy cover. Along stream corridors where overstory does not exist or is thin, vegetation includes shrubs and small trees such as thin-leaf alder (*Alnus sinuata*), willows (*Salix spp*.), snowberry (*Symphoricarpos albus*), Rocky Mountain maple (*Acer glabrum*), red-osier dogwood (*Cornus stolonifera*), blue elderberry (*Sambucus cerulea*), and black hawthorn (*Crataegus douglasii*). Where tree canopy is present, tree species include black cottonwood (*Populus trichocarpa*), water birch (*Betula occidentalis*), quaking aspen (*Populus tremuloides*), and a mix of conifer species including western red cedar, western hemlock (*Tsuga heterophylla*), Douglas fir (*Psuedotsuga menziesii*), grand fir (*Abies grandis*), Ponderosa pine (*Pinus ponderosa*), and western white pine (Pinus monticola). White pine stands have been significantly impacted by white pine blister rust, an introduced pathogen.

Affected areas have been replanted with rust-resistant varieties by the US Forest Service since the mid-1970s, but the replanted area represents only a small part of the area previously occupied by white pine.

Conifer forests in the watershed consist of mixed stands, typified by stands of western red cedar/western hemlock, stands of co-dominant Douglas fir and Ponderosa pine, and stands of Douglas fir, western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), and western white pine. Dense stands of Douglas fir, larch, and lodgepole pine are characteristic of slopes with north and east aspects. Relatively open stands of Douglas fir and Ponderosa pine are typically on the warmer, dryer slopes with south and west aspects.

Representative species of upland shrubs include western serviceberry (*Alelachier alnifolia*), Rocky Mountain maple, snowberry, mountain balm (*Ceanothus velutinus*), mallow ninebark (*Physocarpus malvaceus*), and huckleberry (*Vaccinium spp.*).

Vegetation can strongly influence stream conditions. Canopy cover adjacent to streams provides shade and helps to maintain cooler water temperatures during summer months. Conifers may also provide insulation during winter months, reducing freezing and formation of anchor ice. Large trees that fall into streams and floodplains help to shape channels, create pools, provide cover, introduce and store nutrients, dissipate stream energy, and contribute to overall stream stability. Riparian vegetation also plays an important role in providing stream bank stability through binding of soils by roots. The amount, type, and stage of vegetation in a watershed can also influence stream flows. Vegetation removal by fire or timber harvest can result in increased peak flows during storm events and increased summer flows. Increased peak flows during winter months, when bull trout eggs are hatching, may decrease survival rates.

Fisheries and Aquatic Fauna

There are four salmonids native to the Lower Clark Fork subbasin: westslope cutthroat trout; bull trout; pygmy whitefish; and mountain whitefish (IDFG 2001). Other native and non-native species in the subbasin are listed in Table X. Most of the non-native fishes are found in the warmer, lower portions of the subbasin near the mouth of the Clark Fork River. Species such as black crappie, brown bullhead, largemouth bass, pumpkinseed sunfish, and yellow perch are generally associated with warmer water habitat like that found in the Clark Fork River Delta. Early settlers wanting to establish a fishery stocked with familiar fish introduced these warm water species into the system. Cold water non-native fish were introduced as game fish, or, like the kokanee salmon, migrated downstream from the Flathead River in Montana in the early 1930s (IDFG 2001).

Table X. Fishes in the Lower Clark Fork River Subbasin[1].

Common Name	Scientific Name	Status
Black Crappie	Pomoxis nigromaculatus	Non-native
Brown Bullhead	Ameiurus nebulosus	Non-native
Brown Trout	Salmo trutta	Non-native
Bull Trout	Salvelinus confluentus	Native
Cutthroat Trout	Oncorhynchus clarki	Native
Kokanee Salmon	Oncorhynchus nerka	Non-native
Lake Trout	Salvelinus namaycush	Non-native
Lake Whitefish	Coregonus clupeaformis	Non-native
Largemouth Bass	Micropterus samoides	Non-native
Largescale Sucker	Catostomus macrocheilus	Native
Longnose Sucker	Catostomus catostomus	Native
Mountain Whitefish	Prosopium williamsoni	Native
Northern Pikeminnow	Ptychocheilus oregonensis	Native
Peamouth Chub	Mylocheilus caurinus	Native
Pumpkinseed Sunfish	Lepomis gibbosus	Non-native
Rainbow Trout	Oncorhynchus mykiss	Native
Redside Shiner	Richardsonius balteatus	Native
Slimy Sculpin	Cottus cognatus	Native
Tench	Tinca tinca	Native
Yellow Perch	Perca flavescens	Non-native

[1]Presence of fishes as reported in 1994 Evaluation of Fish Communities on the Lower Clark Fork River, Idaho (WWP 1995).

Because of declining populations throughout their range, bull trout are a species of special concern in this watershed. Bull trout were listed as threatened by the U.S. Fish and Wildlife Service under the Federal Endangered Species Act in 1998. Despite adverse impacts of land use practices leading to the degradation of critical habitat, bull trout can be found in most Lower Clark Fork River drainages where they occurred historically. However, declines in distribution and abundance have been observed (USFWS 2003).

Prior to the federal listing of bull trout, a Bull Trout Conservation Plan was introduced by the office of Idaho Governor Philip Batt. This plan identifies the entire Lake Pend Oreille Basin, including all subbasins draining to the lake, as a key bull trout watershed recommended for habitat protection and restoration (Batt 1996). A Bull Trout Problem Assessment and Conservation Plan have been completed for the Lake Pend Oreille key watershed and identified priorities that should be incorporated into the implementation phase of this TMDL.

According to surveys completed prior to the 1998 Problem Assessment (PBTTAT 1998), Johnson, Twin, Lightning, East Fork Lightning, Savage, Char, Porcupine, Wellington, and Rattle Creeks as well as the mainstem Clark Fork River are utilized for spawning and recruitment. In the mainstem, bull trout make use of a spawning channel that was installed as part of the mitigation package accompanying the construction of the Cabinet Gorge Dam in the 1950s.

Bull trout are thought to be highly sensitive to temperature with spawning areas often associated with spring fed areas where water temperatures are less than 10° C (Pratt 1996). Several streams in the watershed are subject to special temperature criteria established by the EPA to reflect the current or historical presence of bull trout. These EPA listed bull trout streams include: Cascade Creek, East Fork Creek, Johnson Creek, Lightning Creek, Mosquito Creek, Porcupine Creek, Rattle Creek, Spring Creek, Twin Creek, and Wellington Creek.

Historically, bull trout were associated with the lower ends of transport reaches in gradients of 2-8%. The majority of the channels of this type are in East Fork, Char, Savage, Rattle, Porcupine, Middle Lightning and Morris Creeks (PWA 2004). Current distribution is impacted by altered stream stability and other factors in some of these reaches. With the exception of West Fork Blue Creek, the Bull Trout Problem Assessment team (PBTTAT 1998) rated current conditions for bull trout throughout the Lower Clark Fork subbasin as poor to fair. However, the majority of the streams are considered high priority for restoration and/or protection given the high potential to increase bull trout numbers. Appendix X contains detailed excerpts of the bull trout problem assessment.

Additionally, the State of Idaho considers the westslope cutthroat trout (*Oncorhynchus clarki lewisi*) to be a species of special concern, and Region 1 of the U.S. Forest Service has determined the fish to be a sensitive species. Studies have shown that cutthroat spawning areas in the basin are poorly defined and that potential spawning sites are patchy at best (citation? Check Pratt). However, it is suspected that pure strains of westslope cutthroat continue to exist throughout the basin, most likely in headwater areas located above natural migration barriers such as Char Falls, Wellington Creek Falls, Rattle Creek Falls, and Johnson Creek Falls. Mature cutthroat trout are also known to use the mainstem of the river, preferring areas with gravel substrates (Pratt 1996).

The Idaho Department of Fish and Game (IDFG) enforces several fishing regulations for the purpose of protecting bull trout and westslope cutthroat trout. In 1996, the Clark Fork basin was closed to the harvest of bull trout (IDFG 2001). If bull trout are hooked while anglers are fishing for other species, the bull trout must be released unharmed. In addition, the mainstem river has a cutthroat limit of two fish per day, if over 16 inches. Lightning Creek and its tributaries are limited to fishing from Memorial Day weekend to the end of August and have a catch limit of two trout of any kind, with the exception of bull trout.

Throughout the subbasin, the decline in bull trout and cutthroat populations has been attributed to a legacy of road construction, and timber harvest that impact stream stability and habitat. In the case of bull trout, some subwatersheds experience poaching pressure. Both species prefer instream habitat conditions of cold, clear water, riffles, runs, and pool tail-outs with gravel beds low in percent fines for spawning; and deep pools with complex cover for feeding, resting, and over-wintering. Many of the subwatersheds exhibit excess bedload, loss of large woody debris and altered water delivery and flow patterns that result in unstable channels. These factors are believed to be major limiting factors to bull trout populations in much of the Lightning Creek watershed and its tributaries (PBTTAT 1998).

Bull trout have specific habitat requirements and are often associated with spring fed areas in the watershed where there are cool water sources. Bull trout generally spawn from late August through November (Needham and Vaughn 1952, Pratt 1985 cited in PBTTAT 1998) and spawning activity generally peaks in mid-October. Water temperature is a critical factor is determining habitat for bull trout (PBTTAT 1998):

> Water temperature is likely an important and inflexible habitat requirement for bull trout, but its influence on bull trout distribution has not been completely defined.

Temperatures above 59˚ F (15 ˚ C) are thought to limit distribution (Allan 1980, Brown 1992, Fraley and Shepard 1989, Goetz 1991, Oliver 1979, Pratt 1984, Saffel and Scarnecchia 1995, Shepard et al. 1984), while optimum temperatures for rearing are reported to be 44˚ to 47˚ F (7˚ to 8˚C) (Goetz 1989). Saffel and Scarnecchia (1995) observed that juvenile bull trout densities in Pend Oreille tributaries increased with temperature up to 50 ˚ F (10˚C). Rieman and McIntyre (199) observed that distribution of bull trout rearing habitat during summer months was linked to elevation, with higher elevations correlating to cooler stream temperatures. Bull trout spawn at temperatures near 46˚F (8˚C).

In addition to temperature influences on spawning and rearing, unstable stream structure and widening or lack of canopy cover can both increase probability of winter freezing that may impact wintering bull trout.

Subwatershed Characteristics

In this assessment, the Lower Clark Fork River subbasin is divided into 12 subwatersheds. Most of the watersheds are named for the single waterbody that drains it. For the purposes of this assessment, the Clark Fork River Sidewalls includes the mainstem river, Mosquito Creek, and Gold Creek. South-north watersheds draining into the mainstem are: Johnson Creek; Twin Creek, including Dry Creek; Derr Creek; West Fork Blue Creek; and West Fork Elk Creek. The Lightning Creek watershed has been divided into three sections: Upper Lightning Creek, headwaters to Rattle Creek; Middle Lighting Creek, including the mainstem from Rattle Creek to East Fork Creek, and Porcupine Creek; and Lower Lightning Creek, East Fork Creek to the mouth, including Morris Creek. Lightning Creek tributaries treated separately are: Wellington Creek; Cascade Creek; and Rattle Creeks.

Several attributes of each subwatershed are shown in Table X.

Table X. Watershed Characteristics of the Lower Clark Fork River Subbasin.

Watershed	Area (mi^2)	Land Form	Dominant Aspect	Relief Ratio	Mean Elevation (feet)	Dominant Slope
Clark Fork River Sidewalls	43.0	Glacial Valley	West	.09	3,731	14%
Cougar Creek Sidewalls	6.5	Mountainous	Southwest	.09	3,418	28%
Derr Creek	7.6	Mountainous	North	.14	4,172	50%
Dry Creek	23.0	Mountainous	Northeast	.13	4,179	50%
East Fork- Savage Creeks	20.0	Mountainous	Southwest	.11	5,653	30%
Johnson Creek	14.0	Mountainous	Northeast	.12	4,152	50%
Lightning Creek						
Upper Lightning	21.0	Mountainous	South	.10	5,749	29%
Middle Lightning	16.2	Mountainous	Southeast	.11	5,350	30%
Lower Lightning	28.1	Mountainous	Southwest	.12	4,800	28%
Wellington Creek	9.8	Mountainous	Northeast	.13	5,440	30%
Rattle Creek	10.5	Mountainous	Northwest			
West Fork Blue Creek (in Idaho)	5.6	Mountainous	North	.16	4,896	28%
West Fork Elk Creek (in Idaho)	6.2	Mountainous	East	.15	4,263	50%

Stream Characteristics

A total of approximately 115,000 acres are reviewed in this assessment. All of the perennial streams in the Lower Clark Fork River subbasin share similar geologic and vegetative characteristics. The mountainous streams pass through Precambrian Belt Supergroup metasediments, interspersed with glacial till. In the lower elevations, the mouths of creeks feeding into the Clark Fork River flow through glacial debris and unconsolidated alluvium. Cedar-hemlock forests can be found in the lower elevations, while mixed conifer forests consisting of Douglas fir, grand fir, western red cedar, larch, hemlock, ponderosa pine, lodgepole pine, and western white pine are located higher up in the watershed. Alder and willow grow in very wet areas. Subalpine fir, spruce, alder, alpine meadows, and brush fields can be found at the highest elevations (CWE 2003).

Additional physical watershed characteristics are described below. Specific water quality information and beneficial use support status is discussed in Section 2. Streams are characterized using the Rosgen stream typing criteria based upon the morphological features of the river, including valley types, materials, gradients, shapes and meander patterns. This universal classification system helps to predict changes in streams over time, based on comparisons with other rivers of the same classification. (This stream typing can be a useful reference when establishing water quality targets and expected outcomes of restoration activities.) See Appendix X for illustrations of Rosgen stream types. Stream gradients are given as an indicator of steepness, which indicates the amount of sediment and bedload that may be transported or deposited in the system, and in some cases, fish habitat is linked with particular gradients. Width to depth ratios are an indicator of the stability of a stream system and along with other characteristics, indicate a stream's ability to dissipate the energy.

A more extensive review of specific watershed information on streams located within the Lightning Creek is available in the Lightning Creek Watershed Assessment (PWA et al 2004).

Clark Fork River

For the purposes of this assessment, the river consists of the main stem of the Clark Fork from the Montana border to the river's mouth, including all river delta channels, and Mosquito Creek for a total of drainage area of 115,204 acres. The river is an eighth order stream at its mouth, and has a gradient of .05%. The river's average width to depth ratio is 145.1.

The Clark Fork River is approximately 11 miles (18 km) long from the Idaho-Montana border to Pend Oreille Lake. Its consists of a main channel, a side channel at Foster Rapids, and a large delta at its mouth. The main channel has two riffles (Whitehorse and Foster Rapids) and several large, deep pools with a maximum depth of 76 feet (23 m). River-like conditions persist in the channel downstream to the second vehicle bridge (now closed) at the City of Clark Fork. Beyond this point, varying lake levels begin to influence velocity, depth, and general hydraulic conditions in the lower river channel and the delta.

Mosquito Creek is a second order stream with a gradient of 2%, flowing into the river from the north. It has a Rosgen B, u-shaped channel with an average width to depth ratio of 42.6.

Cougar and Spring Creek

Cougar Creek is a small first order stream located on the western edge of the Lower Clark Fork River subbasin. Cougar Creek appears to drain into Denton Slough, and therefore, will be reassigned to a separate assessment unit from Spring Creek, which drains into Lower Lightning Creek.

Spring Creek is a second order, 6465 acre stream draining into Lower Lightning Creek.

Derr Creek

Derr Creek is a 4,973 acre watershed located on the southern side of the Clark Fork River. Stream and floodplain alterations interrupt flow before the Creek reaches the Clark Fork River (PBTTAT 1998).

Twin-Dry Creeks

In this assessment Twin Creek is defined as the creek itself and Dry Creek, totaling 14,882 acres. Twin and Dry Creeks are located on the southern side of the Clark Fork River, just east of Derr Creek. Twin Creek is a third order stream with a Rosgen A type channel. The stream flows down a v-shaped valley and has a gradient of 4%. Twin Creek's average width to depth ratio is 16.1. BURP data were collected on Twin Creek in 1995 and 2001.

Dry Creek is a second order stream. Stream and floodplain alterations interrupt flow before the Creek reaches the Clark Fork River (PBTTAT 1998). Dry creek is reportedly dry except for during spring run-off.

East Fork-Savage Creeks

East Fork and Savage Creeks are located in the middle third of the Lower Clark Fork subbasin, on the far eastern side. In Idaho, they total 12,630 acres with the headwaters of each stream originating in Montana and flowing down a u-shaped valley. East Fork Creek is a third order stream, while Savage Creek is a second order stream that feeds into East Fork Creek. East Fork Creek is a Rosgen A type channel, with a 4% gradient near the mouth and a 6% gradient farther upstream. It has an average width to depth ratio of 52.9. Savage Creek also has a gradient of 6%. Its channel type is Rosgen A, and its average width to depth ratio is 17.3.

Johnson Creek

The Johnson Creek watershed encompasses Johnson Creek and the West Fork of Johnson Creek. They total 9,960 acres of Rosgen B type channels located on the southern side of the Clark Fork River near the river's mouth. Johnson Creek runs through a v-shaped valley at a 3% gradient in the upper portion of the watershed and a 1.5% gradient near the mouth. The stream's width to depth ratio is 93.2.

Lightning Creek

Lightning Creek is the Clark Fork River's largest tributary in Idaho, entering the river from the north, just above the river delta. For the purposes of this assessment, Lightning Creek includes the main stem of Lightning Creek and Cascade, Morris, Porcupine, Rattle, and Spring Creeks, which are all second order streams. The main stem of Lightning Creek and its tributaries have been divided into three sections: Upper; Middle; and Lower Lightning Creek.

Upper Lightning Creek is a 13,478 acre watershed (CWE 2003), extending from the headwaters to Rattle Creek. It is a third order Rosgen A type channel with a flat bottom. The gradient of the upper portion of the creek is 6% and the average width to depth ratio is 90.

Middle Lightning Creek drains approximately 10,368 acres, beginning at Rattle Creek and ending at East Fork Creek. The Creek changes from a transport reach (2-4% gradient) to a response reach (<2% gradient) near Wellington Creek (PWA 2004). The channel type is Rosgen B and the average width to depth ratio is 54.6.

Lower Lightning Creek is a fourth order stream that begins at East Fork Creek and extends to the mouth of Lightning Creek. This section is an approximately 17,600 acre watershed (CWE 2003) and has a 1% gradient. The channel type is Rosgen C with a flat bottom. The average width to depth ratio in this portion of the stream is 92.2.

Lightning Creek's smallest tributary, Morris Creek, is located on the eastern side of the creek, just south of Savage Creek. The gradient of Morris Creek is 4% and the channel type is Rosgen B. Morris Creek's average width to depth ratio is 11.8.

The next largest tributary of Lightning Creek is Cascade Creek, located on the eastern side of the creek near its mouth. Cascade Creek has a flat-bottomed, Rosgen C type channel and an average width to depth ratio of 26.8.

Just opposite of Cascade Creek is Spring Creek, a Rosgen B type stream with a trough-like channel and a 3% gradient.

Porcupine Creek is located directly north of Cascade Creek, on the western side of Lightning Creek. It has a u-shaped, Rosgen A type channel, with a 4% gradient. The stream's average width to depth ratio is 32.8.

Rattle Creek

Rattle Creek, a 6,824 acre watershed, is Lightning Creek's northernmost and largest tributary. Rattle Creek is the watershed's steepest, with a 7% gradient. It is a u-shaped, Rosgen A type channel. The average width to depth ratio of Rattle Creek is 35.8.

Wellington Creek

Wellington Creek is a third order tributary of Lightning Creek and a 6,790 acre watershed. It is centrally located in the western side of the Lightning Creek watershed. Wellington Creek is 7.9 miles long and has a gradient of 4%. It has a v-shaped, Rosgen A channel. The lowest reach is a bedrock canyon, with a fish barrier falls less than one-third mile upstream of the confluence with Lightning Creek. The stream's average width to depth ratio is 45.1.

West Fork of Blue Creek

The West Fork of Blue Creek is located on the far western side of the Subbasin. It originates in Idaho and flows into Montana. The headwaters portion in Idaho consists of 3,858 acres.

West Fork of Elk Creek

The West Fork of Elk Creek and is located on the far western side of the Subbasin, flowing into Montana. It is intermittent and will not be addressed further in this assessment.

Cascade Creek

Cascade Creek is a 3,849 acres watershed and a second order tributary to Lightning Creek. Cascade Creek is located low in the Lightning Creek watershed on the eastern side of Lightning Creek and orientated with an east-west aspect. Cascade Creek exhibits a 1.5% gradient in the lower Rosgen C type channel. The average width to depth ratio of Cascade Creek is 20.

1.3 Cultural Characteristics

The Lower Clark Fork River subbasin is a rural residential community. The watershed's most dense populations can be found in the river valley, where homes and businesses are clustered within the City of Clark Fork. The remaining population is scattered between large farming operations on the river's floodplain and mountain retreats higher up in the watershed.

Land Use

Land use in the Lower Clark Fork River subbasin is shown in Figure X. Land use is divided between the mountainous uplands and the sloping floodplains of the river bottom. The mountainous areas of the watershed are forested, while the floodplains are mostly grasslands used for hay production. Until recently, the area was characterized by little land use change. However, over the past two years (2004-2005), dramatic, increasing development pressures in the Sandpoint area and surrounding Lake Pend Oreille are likely to draw people to nearby areas like Clark Fork. Because of the large public ownership in the forested areas of the subbasin, development is likely to follow current patterns, focusing on the valley areas along the mainstem and the south side of the river. This could create future water quality challenges, as the City of Clark Fork is currently completely serviced by aging septic systems. An increase in population and building in the area will likely increase the number of septic systems and could impact the water quality in the Clark Fork River with additional nutrient inputs, in addition to sediment and nutrients typical to all housing and development activities.

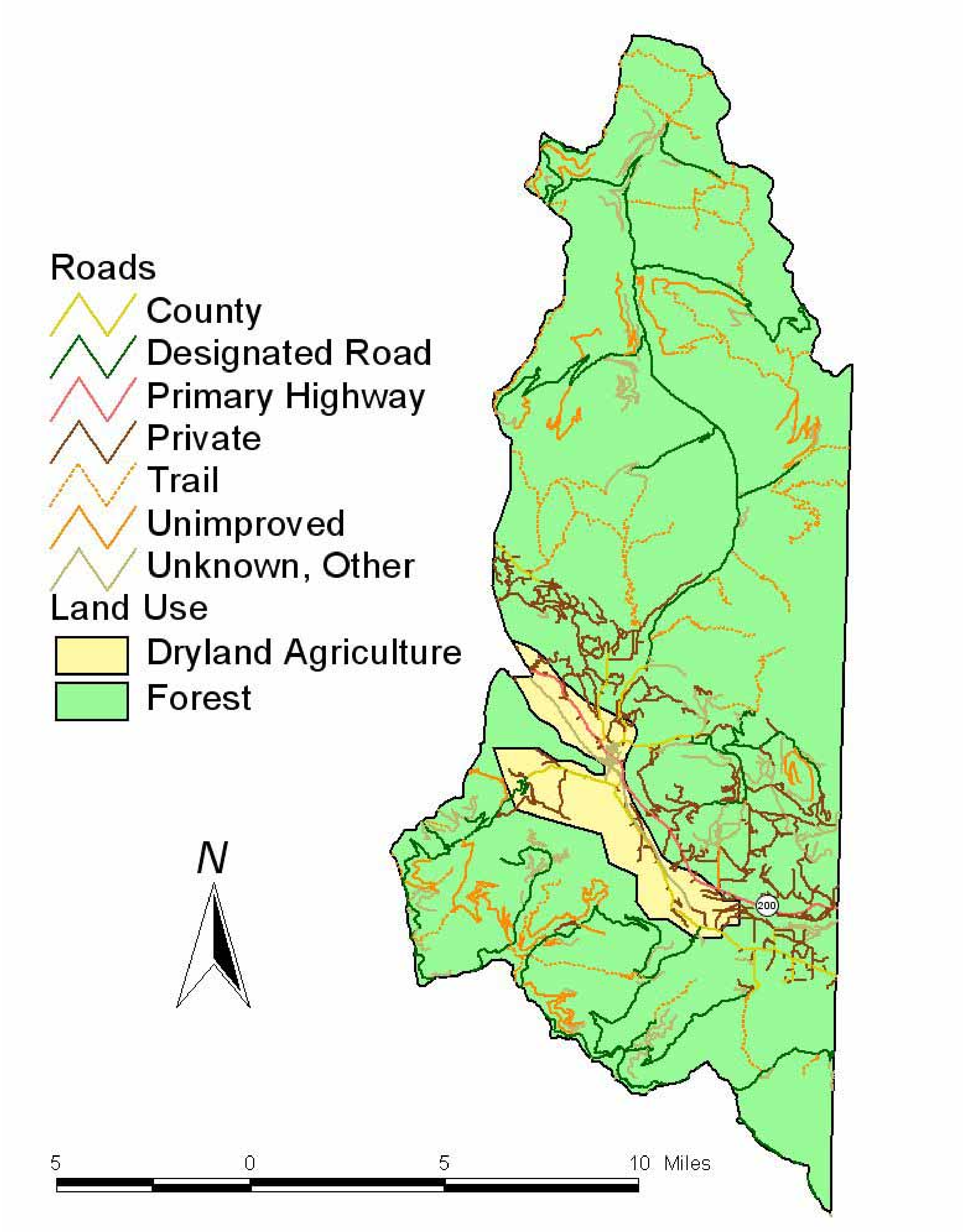


Figure X. Lower Clark Fork Subbasin Land Use and Roads

Land Ownership, Cultural Features, and Population

The Lower Clark Fork River subbasin is located entirely in Bonner County. The population of the county is 36,835 (2000 Census). The only town located in the subbasin is the City of Clark Fork, incorporated in 1912. The city has a population of approximately 530 residents and encompasses nearly one square mile of land on the north side of the river. Its elevation is 2,084 feet above sea level.

Land ownership in the watershed is divided between private, state, and federal lands (Figure X). There are 31,653 acres of privately owned property in the subbasin. Private property is generally located at lower elevations in the watershed. It comprises 23% of the watershed. The Bureau of Land Management (BLM) manages 1,404 acres or .01% the subbasin, primarily located in the river valley. The state of Idaho owns .02% of the subbasin, which is just over 2,711 acres. Like privately owned and BLM lands, state lands are located in the river valley. The largest land manager in the subbasin is the US Forest Service, which manages 74% of the watershed (101,505 acres). The remainder of the subbasin is water.

Several recreation areas are located within the subbasin and the forested areas are popular winter and summer recreation sites. There is an USFS campground at Porcupine Lake, and a non-USFS campground at the mouth of Johnson Creek. A sportsman's access and two boat launches are located along the river. Additionally, the IDFG manages the Clark Fork Game Management area located at the mouth of the Clark Fork River.

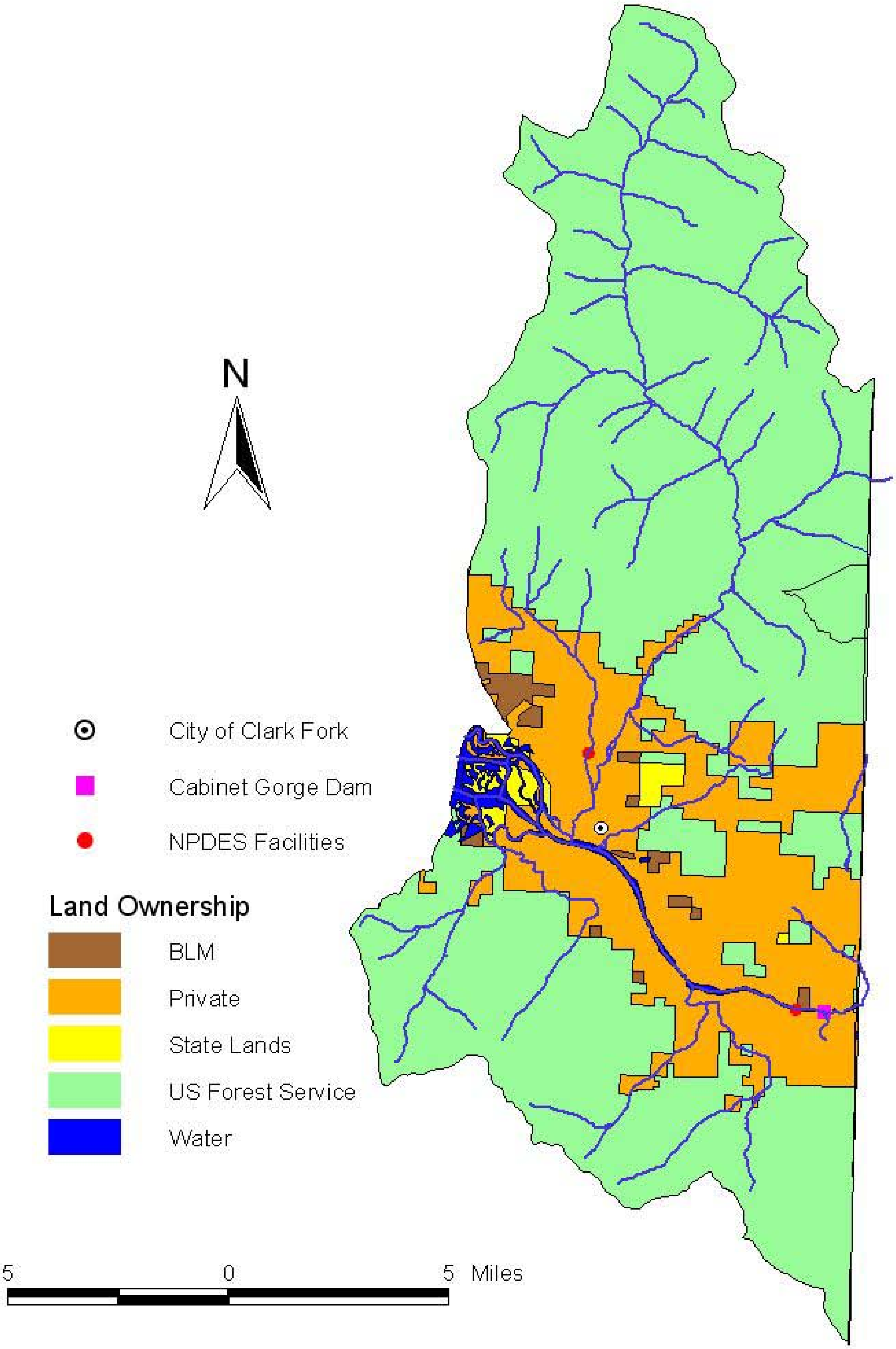


Figure X. Land Ownership in the Lower Clark Fork River Basin

History and Economics

Historically, the principal economic activities in the Lower Clark Fork Subbasin were mining, logging, sawmills, and farming. Sawmill activity flourished up until World War II, while mining activities were central to the subbasin's economy until the 1950's. The subbasin's mines produced galena ore, the source of lead, silver, and zinc. Small prospecting claims are located throughout the watershed, but the commercially operated mines were located near the present-day Spring Creek Fish Hatchery, on Antelope Mountain, and near the previous location of the University of Idaho Field Campus (Key 2003).

The early 1950's brought construction of the Cabinet Gorge Dam. The dam is a hydropower project operated by Avista Corporation. Construction was completed in 1952. The arch-type dam spans the width of the 600 foot wide channel. It is 208 feet high with a licensed generating capacity of 231 megawatts. The minimum flow allowed over the dam is 5,000 cubic feet per second. Inside the dam are one Kaplan, one mixed flow, and two propeller turbines. The reservoir behind the dam is capable of storing 42,780 acre feet of water.

Current activities include a handful of large farms, commercial timber harvest on private and federally owned lands, and two state operated fish hatcheries. The Clark Fork fish hatchery is located on Spring Creek, 1.5 miles northwest of the city of Clark Fork. It was completed in 1938 to house westslope cutthroat trout, brook trout, brown trout, golden trout, rainbow trout, Arctic grayling, and kokanee and has been closed to operation since 2001. The Bonneville Power Administration and the IDFG built the second hatchery in 1985. The hatchery, operated by IDFG, is located approximately one mile downstream of the Cabinet Gorge dam and produces mostly kokanee (Avista 2003).

The historically diverse land uses and economic activities in the Clark Fork River drainage area have led to an associated range of water quality problems. Many agencies, citizen groups, local businesses and governments have come together to address water quality issues throughout the Lower Clark Fork River Subbasin in Idaho and Montana. Two significant efforts include an agreement between Avista and interested stakeholders to mitigate for impacts of its major hydropower developments on Clark Fork River, and the Tri-State Water Quality Council, a collaboration that includes Washington, Idaho and Montana stakeholders, with the goal to manage and improve water quality in the entire Clark Fork-Pend Oreille system.

2. Subbasin Assessment – Water Quality Concerns and Status

This section contains an assessment of water quality concerns and status for all ten of the water quality impaired subwatersheds in the Lower Clark Fork River subbasin. Twenty-four water quality limited segments within these subwatersheds are identified in this section, along with a discussion of the applicable water quality standards for these water bodies, existing water quality data, and data gaps. Monitoring performed by DEQ, Avista Utilities, the Tri-State Water Quality Council and the USFS has identified water quality concerns in these subwatersheds.

2.1 Water Quality Limited Assessment Units Occurring in the Subbasin

The Clean Water Act mandates that the chemical, physical, and biological integrity of the nation's waters be restored and maintained (33 USC §§ 1251 – 1387). In accordance with this mandate, the State of Idaho has adopted water quality standards per section 318 of the CWA, to protect fish, shellfish, and wildlife while providing recreation in and on water whenever attainable. As required by section 303(d) of the CWA the state must identify and prioritize water bodies that are water quality limited. The list of water quality limited waters is published every two years. TMDLs are then developed for waters identified on the list, set at a level to achieve the state's water quality standards.

The river and its tributaries on the 303(d) list for impairment due to metals, sediment, and temperature are shown in Table X. A discussion of the pollutants, available data, beneficial uses, and exceedences of standards is presented in the following sections.

Section 303(d) of the CWA states that waters that are unable to support their beneficial uses and that do not meet water quality standards must be listed as water quality limited waters. Subsequently, these waters are required to have TMDLs developed to bring them into compliance with water quality standards. In 2002, the DEQ further refined its system of managing data for water quality limited streams by establishing assessment units throughout the state. This new process is described below.

<u>About Assessment Units</u>

Assessment units (AUs) are groups of similar streams that have similar land use practices, ownership, or land management. Stream order, however, is the main basis for determining AUs—although ownership and land use can change significantly, the AU remains the same. AUs now define all the waters of the state of Idaho. These units and the methodology used to describe them can be found in the Water Body Assessment Guidance II (Grafe et al. 2002).

Using assessment units to describe water bodies offers many benefits, the primary benefit being that all the waters of the state are now defined consistently. In addition, using AUs fulfills the fundamental requirement of EPA's 305(b) report, a component of the Clean Water Act wherein states report on the condition of all the waters of the state. Because AUs are a subset of water body identification numbers, there is now a direct tie to the water quality standards for each AU, so that beneficial uses defined in the water quality standards are clearly tied to streams on the landscape.

However, the new framework of using AUs for reporting and communicating needs to be reconciled with the legacy of 303 (d) listed streams. Due to the nature of court-ordered 1994 303(d) listings, and the subsequent 1998 303(d) list, all segments were added with boundaries from “headwater to mouth.” In order to deal with the vague boundaries in the listings, and to complete TMDLs at a reasonable pace, DEQ set about writing TMDLs at the watershed scale (using standardized Hydrologic Unit Code delineations), so that all the waters in the drainage area have been considered for TMDL purposes since 1994.

The boundaries from the 1998 303(d) listed segments have been transferred to the new AU framework, using an approach quite similar to how DEQ has been writing Subbasin Assessments and TMDLs. All AUs contained in the 1998 listed segment were carried forward to the 2002 303(d) listings in the Integrated Report. AUs not wholly contained within a previously listed segment, but partially contained (even minimally), were also included on the 303(d) list. This was necessary to maintain the integrity of the 1998 303(d) list and to maintain continuity with the TMDL program. These new AUs will lead to better assessment of water quality listing and de-listing of those segments that do not exceed water quality standards.

When assessing new data that indicate full support of beneficial uses, only the AU that the monitoring data represents will be removed (de-listed) from the 303(d) list (Section 5 of the Integrated Report.).

Listed Waters

Table X shows the pollutants listed and the boundaries of each §303(d) listed AU in the subbasin. Not all of the water bodies will require a TMDL, as will be discussed later. However, a thorough investigation, using the available data, was performed before this conclusion was made. This investigation, along with a presentation of the evidence of non-compliance with standards for several other tributaries, is contained in the following sections.

Table X. §303(d) Segments in the Lower Clark Fork River Subbasin.

Water Body Name	Assessment Unit	2002 §303(d) Boundaries	Pollutants	Beneficial Uses[A]
Clark Fork River	17010213PN005_08	Mainstem Clark Fork River from the Idaho/Montana Border to Cabinet Gorge Dam	TDG, Metals,toxics, Unknown, Temperature	CWAL, SS, PCR, DWS, SRW (Designated)
	17010213PN003_08	Mainstem Clark Fork River from Cabinet Gorge Dam to Mosquito Creek		
	17010213PN001_08	Mainstem Clark Fork River Mosquito Creek to Lake Pend Oreille		
Cascade Creek	17010213PN012_02	First and second order portions of Cascade Creek, including the mainstem to Lightning Creek	Temperature	CWAL, SS, SCR (Existing)
Dry Creek	17010213PN004_02	First and second order portions of Dry Creek, including mainstem Dry Creek, Delyle Creek, and Twin Creek upstream of Delyle Creek	Temperature	CWAL, SS, SCR (Existing)
Twin Creek	17010213PN004_03	Third order portion of mainstem Twin Creek from Delyle Creek to the Lower Clark Fork River	Temperature	CWAL, SS, SCR (Existing)
East Fork Creek	17010213PN014_02	First and second order portions of East Fork Creek, including mainstem East Fork Creek from Idaho/Montana border to Savage Creek	Temperature, Sediment	CWAL,SS, SCR (Existing)
	17010213PN014_03	Third order portion of mainstem East Fork Creek from Savage Creek to Lightning Creek		
Johnson Creek	17010213PN002_02	First and second order portions of Johnson Creek, including West Johnson Creek	Temperature, Sediment	CWAL, SS, PCR (Existing)
	17010213PN002_03	Third order portion of Johnson Creek to Clark Fork Delta		

Water Body Name	Assessment Unit	2002 §303(d) Boundaries	Pollutants	Beneficial Uses[A]
Upper Lightning Creek	17010213PN0019_02	First and second order portions of Lightning Creek from source to Rattle Creek	Temperature, Unknown	CWAL, SS, PCR, DWS, SRW (Designated)
	17010213PN0019_03	Third order portion of mainstem Lightning Creek from Fall Creek to Rattle Creek		
Middle Lightning Creek	17010213PN0017_02	First and second order portions of Lightning Creek from Rattle Creek to Wellington Creek, including Sheep and Bear Creeks	Temperature, Unknown	CWAL, SS, PCR, DWS, SRW (Designated)
	17010213PN0017_03	Third order portion of mainstem Lightning Creek from Rattle Creek to Wellington Creek		
	17010213PN0016_02	First and second order portions of Lightning Creek from Wellington Creek to East Fork Creek, including Porcupine Creek		
	17010213PN0016_03	Third order portion of Lightning Creek mainstem from Wellington Creek to East Fork Creek		
Lower Lightning Creek	17010213PN0013_02	First and second order portions of Lightning Creek from East Fork Creek to Cascade Creek, including Morris Creek	Temperature, Unknown	CWAL, SS, PCR, DWS, SRW (Designated)
	17010213PN0013_04	Fourth order portion of mainstem Lightning Creek from East Fork Creek to Cascade Creek		
	17010213PN0011_02	First and second order portions of Lightning Creek from Cascade Creek to Spring Creek		
	17010213PN0011_04	Fourth order portion of mainstem Lightning Creek from Cascade Creek to Spring Creek		

Water Body Name	Assessment Unit	2002 §303(d) Boundaries	Pollutants	Beneficial Uses[A]
	17010213PN0010_04	Fourth order portion of mainstem Lightning Creek from Spring Creek to Clark Fork River		
Rattle Creek	17010213PN018_02	First and second order portions of Rattle Creek from headwaters to Lightning Creek	Temperature	CWAL,SS, SCR (Existing)
Savage Creek	17010213PN015_02	First and second order portions of Savage Creek from the Idaho/Montana border to East Fork Creek	Temperature	CWAL,SS, SCR (Existing)
Wellington Creek	17010213PN020_02	First and second order portions of Wellington Creek from the headwaters to Lightning Creek	Temperature, Sediment	CWAL,SS, SCR (Existing)

[a] CWAL – cold water aquatic life, SS – salmonid spawning, PCR – primary contact recreation, SCR – secondary contact recreation, AWS – agricultural water supply, DWS – domestic water supply, SRW – special resource water

In addition to those pollutants listed in Table X, all AUs in the mainstem Clark Fork River and Johnson Creek were included on the 2002 Integrated Report, Section 4C, "Rivers Impaired by Flow or Habitat Alteration" (DEQ 2002). DEQ recognizes that these impairments impact water quality. However, because habitat and flow alterations are characterized as pollution, but are not actually measurable pollutants, it is DEQ policy to not develop TMDLs for these impairments.

2.2 Applicable Water Quality Standards

Existing beneficial uses and water quality standards for water bodies in the Lower Clark Fork subbasin are discussed below. Designated beneficial uses for the Lower Clark Fork include cold water aquatic life, salmonid spawning, primary contact recreation, domestic water supply, and special resource water (IDAPA 58.01.02.04). The designated beneficial uses of the §303(d) listed tributaries are presented in Table X. Section 303(d) listed tributaries that have not had beneficial uses designated have been assigned existing beneficial uses. These include cold water aquatic life, salmonid spawning, and primary or secondary contact recreation (IDAPA 58.01.02.101.01). Narrative and numeric water quality standards relevant to designated beneficial uses are also discussed in this section. More information on different types of beneficial uses is also provided.

Beneficial Uses

Idaho water quality standards require that surface waters of the state be protected for beneficial uses, wherever attainable (IDAPA 58.01.02.050.02). These beneficial uses are interpreted as existing uses, designated uses, and presumed uses as briefly described in the following paragraphs. The *Water Body Assessment Guidance*, second edition (Grafe et al. 2002) gives a more detailed description of beneficial use identification for use assessment purposes.

Existing Uses

Existing uses under the CWA are “those uses actually attained in the waterbody on or after November 28, 1975, whether or not they are included in the water quality standards.” The existing in-stream water uses and the level of water quality necessary to protect the uses shall be maintained and protected (IDAPA 58.01.02.050.02, .02.051.01, and .02.053). Existing uses include uses actually occurring, whether or not the level of quality to fully support the uses exists. A practical application of this concept would be to apply the existing use of salmonid spawning to a waterbody that could support salmonid spawning, but salmonid spawning is not occurring due to other factors, such as dams blocking migration.

Designated Uses

Designated uses under the Clean Water Act are “those uses specified in water quality standards for each water body or segment, whether or not they are being attained.” Designated uses are simply uses officially recognized by the state. In Idaho, these include uses such as aquatic life support, recreation in and on the water, domestic water supply, and agricultural uses. Water quality must be sufficiently maintained to meet the most sensitive use. Designated uses may be added or removed using specific procedures provided for in state law, but the effect must not be to preclude protection of an existing higher quality use such as cold water aquatic life or salmonid spawning. Designated uses are specifically listed for water bodies in Idaho in tables in the Idaho water quality standards (see IDAPA 58.01.02.003.27 and .02.109-.02.160 in addition to citations for existing uses).

Presumed Uses

In Idaho, most water bodies listed in the tables of designated uses in the water quality standards do not yet have specific use designations. These undesignated uses are to be designated. In the interim, and absent information on existing uses, DEQ presumes that most waters in the state will support cold water aquatic life and either primary or secondary contact recreation (IDAPA 58.01.02.101.01). To protect these so-called “presumed uses,” DEQ will apply the numeric cold water criteria and primary or secondary contact recreation criteria to undesignated waters. If in addition to these presumed uses, an additional existing use, (e.g., salmonid spawning) exists, because of the requirement to protect levels of water quality for existing uses, then the additional numeric criteria for salmonid spawning would additionally apply (e.g., intergravel dissolved oxygen, temperature).

Table X. Lower Clark Fork Subbasin beneficial uses of non-§303(d) listed streams.

Water Body Name	Assessment Unit	2002 Boundaries	Status	Beneficial Uses
West Fork Elk Creek	17010213PN006_02	West Fork Elk Creek Source to Idaho/Montana Border	Not Assessed	CWAL, SS, SCR (Presumed)
West Fork Blue Creek	17010213PN007_02	West Fork Blue Creek source to Idaho/Montana border	Not Assessed	CWAL, SS, SCR (Presumed)
Gold Creek	17010213PN008_02	Gold Creek source to Idaho/Montana border	Not Assessed	CWAL, SS, SCR (Presumed)
Spring Creek	170213PN021_02	Spring Creek Source to confluence with Lightning Creek	Full Support Needs Verification	CWAL, SS, SCR (Presumed)
Johnson Creek delta area	17010213PN001_03	Johnson Creek – third order portion in the delta area of the Lower Clark Fork River	Not Assessed	CWAL, SS, PCR (Presumed)
Clark Fork River	17010213PN003_02	First and second order unnamed tributaries to Clark Fork River	Not Assessed	CWAL, SS, SCR (Presumed)
Derr Creek	17010213PN001_02		Not Assessed	CWAL, SS, SCR (Presumed)
Mosquito Creek	17010213PN009_02	Mosquito Creek source to mouth	Full Support	CWAL, SS, SCR (Presumed)

[a] CW – cold water, SS – salmonid spawning, PCR – primary contact recreation, SCR – secondary contact recreation, AWS – agricultural water supply, DWS – domestic water supply

Criteria to Support Beneficial Uses

Beneficial uses are protected by a set of criteria, which include *narrative* criteria for pollutants such as sediment and nutrients and *numeric* criteria for pollutants such as bacteria, dissolved oxygen, pH, ammonia, temperature, and turbidity (IDAPA 58.01.02.250) (Table X).

Excess sediment is described by narrative criteria (IDAPA 58.01.02.200.08): "Sediment shall not exceed quantities specified in Sections 250 and 252 or, in the absence of specific sediment criteria, quantities which impair designated beneficial uses. Determinations of impairment shall be based on water quality monitoring and surveillance and the information utilized as described in Subsection 350."

Narrative criteria for excess nutrients are described in IDAPA 58.01.02.200.06, which states: "Surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses."

Narrative criteria for floating, suspended, or submerged matter are described in IDAPA 58.01.02.200.05, which states: "Surface waters of the state shall be free from floating, suspended, or submerged matter of any kind in concentrations causing nuisance or objectionable conditions or that may impair designated beneficial uses. This matter does not include suspended sediment produced as a result of nonpoint source activities."

DEQ's procedure to determine whether a water body fully supports designated and existing beneficial uses is outlined in IDAPA 58.01.02.053. The procedure relies heavily upon biological parameters and is presented in detail in the DEQ Water Body Assessment Guidance (Grafe et al. 2002). This guidance requires the use of the most complete data available to make beneficial use support status determinations.

Figure X provides an outline of the stream assessment process for determining support status of the beneficial uses of cold water aquatic life, salmonid spawning, and contact recreation.

Table X. Selected numeric criteria supportive of designated beneficial uses in Idaho water quality standards.

Designated and Existing Beneficial Uses				
Water Quality Parameter	**Primary Contact Recreation**	**Secondary Contact Recreation**	**Cold Water Aquatic Life**	**Salmonid Spawning (During Spawning and Incubation Periods for Inhabiting Species)**
Water Quality Standards: IDAPA 58.01.02.250				
Bacteria, ph, and Dissolved Oxygen	Less than 126 *E. coli*/100 ml[a] as a geometric mean of five samples over 30 days; no sample greater than 406 *E. coli* organisms/100 ml	Less than 126 *E. coli*/100 ml as a geometric mean of five samples over 30 days; no sample greater than 576 *E. coli*/100 ml	pH between 6.5 and 9.0 DO[b] exceeds 6.0 mg/L[c]	pH between 6.5 and 9.5 Water Column DO: DO exceeds 6.0 mg/L in water column or 90% saturation, whichever is greater Intergravel DO: DO exceeds 5.0 mg/L for a one day minimum and exceeds 6.0 mg/L for a seven day average
Tempera-ture[d]			22 °C or less daily maximum; 19 °C or less daily average	13 °C or less daily maximum; 9 °C or less daily average Bull trout: not to exceed 13 °C maximum weekly maximum temperature over warmest 7-day period, June – August; not to exceed 9 °C daily average in September and October
			Seasonal Cold Water: Between summer solstice and autumn equinox: 26 °C or less daily maximum; 23 °C or less daily average	
Turbidity			Turbidity shall not exceed background by more than 50 NTU[e] instantaneously or more than 25 NTU for more than 10 consecutive days.	
Ammonia			Ammonia not to exceed calculated concentration based on pH and temperature.	

Designated and Existing Beneficial Uses				
Water Quality Parameter	**Primary Contact Recreation**	**Secondary Contact Recreation**	**Cold Water Aquatic Life**	**Salmonid Spawning (During Spawning and Incubation Periods for Inhabiting Species)**
EPA Bull Trout Temperature Criteria: Water Quality Standards for Idaho, 40 CFR Part 131				
Tempera-ture				7 day moving average of 10 °C or less maximum daily temperature for June - September

[a] *Escherichia coli* per 100 milliliters
[b] dissolved oxygen
[c] milligrams per liter
[d] Temperature Exemption - Exceeding the temperature criteria will not be considered a water quality standard violation when the air temperature exceeds the ninetieth percentile of the seven-day average daily maximum air temperature calculated in yearly series over the historic record measured at the nearest weather reporting station.
[e] Nephelometric turbidity units

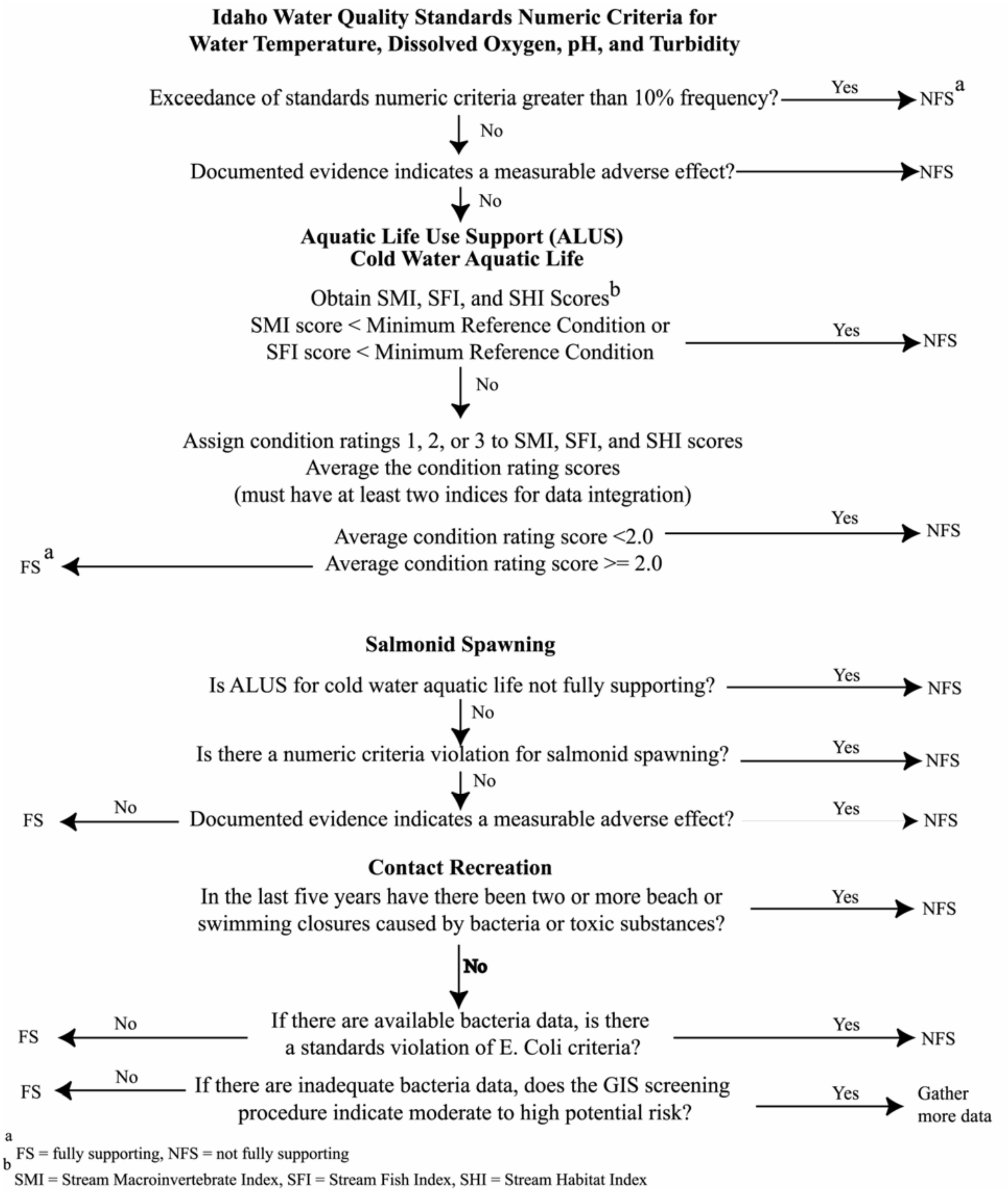


Figure X. Determination Steps and Criteria for Determining Support Status of Beneficial Uses in Wadeable Streams: *Water Body Assessment Guidance*, Second Addition (Grafe et al 2002).

2.3 Pollutant/Beneficial Use Support Status Relationships

Most of the pollutants that impair beneficial uses in streams are naturally occurring stream characteristics that have been altered by humans. That is, streams naturally have sediment, nutrients, and the like, but when anthropogenic sources cause these to reach unnatural levels, they are considered "pollutants" and can impair the beneficial uses of a stream.

The following section describes the most common pollutes in Idaho's waters and the potential impacts on beneficial uses. While the discussion of temperature and sediment are the most relevant to the Lower Clark Fork subbasin, other pollutants covered by the state water quality standards are discussed for general informational purposes. (Note that most streams in the subbasin have not been assessed for many of these pollutants. For example, only the mainstem Clark Fork River was assessed for nutrients.)

Temperature

Temperature is a water quality factor integral to the life cycle of fish and other aquatic species. Different temperature regimes also result in different aquatic community compositions. Water temperature dictates whether a warm, cool, or coldwater aquatic community is present. Many factors, natural and anthropogenic, affect stream temperatures. Natural factors include altitude, aspect, climate, weather, riparian vegetation (shade), and channel morphology (width and depth). Human influenced factors include heated discharges (such as those from point sources), riparian alteration, channel alteration, and flow alteration.

Elevated steam temperature can be harmful to fish at all life stages, especially if it occurs in combination with other habitat limitations such as low dissolved oxygen or poor food supply. Acceptable temperature ranges vary for different species of fish, with cold water species being the least tolerant of high water temperatures. Temperature as a chronic stressor to adult fish can result in reduced body weight, reduced oxygen exchange, increased susceptibility to disease, and reduced reproductive capacity. Acutely high temperatures can result in death if they persist for an extended length of time. Juvenile fish are even more sensitive to temperature variations than adult fish, and can experience negative impacts at a lower threshold value than the adults, manifesting in retarded growth rates. High temperatures also affect embryonic development of fish before they even emerge from the substrate. Similar kinds of affects may occur to aquatic invertebrates, amphibians and mollusks, although less is known about them.

Dissolved Oxygen

Oxygen is necessary for the survival of most aquatic organisms and essential to stream purification. Dissolved oxygen (DO) is the concentration of free (not chemically combined) molecular oxygen (a gas) dissolved in water, usually expressed in milligrams per liter (mg/L), parts per million, or percent of saturation. While air contains approximately 20.9% oxygen gas by volume, the proportion of oxygen dissolved in water is about 35%, because nitrogen (the remainder) is less soluble in water. Oxygen is considered to be moderately soluble in water. A complex set of physical conditions that include atmospheric and hydrostatic pressure, turbulence, temperature, and salinity affect the solubility.

Dissolved oxygen levels of 6 mg/L and above are considered optimal for aquatic life. When DO levels fall below 6 mg/L, organisms are stressed, and if levels fall below 3 mg/L for a prolonged period, these organisms may die; oxygen levels that remain below 1-2 mg/L for a few hours can result in large fish kills. Dissolved oxygen levels below 1 mg/L are often referred to as hypoxic; anoxic conditions refer to those situations where there is no measurable DO.

Juvenile aquatic organisms are particularly susceptible to the effects of low DO due to their high metabolism and low mobility (they are unable to seek more oxygenated water). In addition, oxygen is necessary to help decompose organic matter in the water and bottom sediments. Dissolved oxygen reflects the health or the balance of the aquatic ecosystem.

Oxygen is produced during photosynthesis and consumed during plant and animal respiration and decomposition. Oxygen enters water from photosynthesis and from the atmosphere. Where water is more turbulent (e.g., riffles, cascades), the oxygen exchange is greater due to the greater surface area of water coming into contact with air. The process of oxygen entering the water is called aeration.

Water bodies with significant aquatic plant communities can have significant DO fluctuations throughout the day. An oxygen sag will typically occur once photosynthesis stops at night and respiration/decomposition processes deplete DO concentrations in the water. Oxygen will start to increase again as photosynthesis resumes with the advent of daylight.

Temperature, flow, nutrient loading, and channel alteration all impact the amount of DO in the water. Colder waters hold more DO than warmer waters. As flows decrease, the amount of aeration typically decreases and the instream temperature increases, resulting in decreased DO. Channels that have been altered to increase the effectiveness of conveying water often have fewer riffles and less aeration. Thus, these systems may show depressed levels of DO in comparison to levels before the alteration. Nutrient enriched waters have a higher biochemical oxygen demand due to the amount of oxygen required for organic matter decomposition and other chemical reactions. This oxygen demand results in lower instream DO levels.

Total Dissolved Gas

Total Dissolved Gas (TDG) superstaturation can cause gas bubble disease in fish and other aquatic organisms, and may limit habitat due to the potentially lethal presence of elevated gas levels in prime habitat areas. Idaho water quality criteria for TDG is 110% saturation or less in order to protect aquatic life beneficial uses. TDG supersaturation can occur during spring runoff, when spill at hydroelectric facilities is at its highest. This spill activity causes supersaturation of gas when high volumes of water are passing over spillways because the river flows are exceeding the hydraulic capacity of the dams. Significant volumes of atmospheric gases become entrained by the increased pressure at the pools below dams, and can remain in the river for significant distances. Less turbulent reaches below dams are less-effective at dissipating the entrained gases than more turbulent river systems.

Metals

Metals can be toxic to aquatic organism and fish if absorbed into their systems. The uptake of metals by aquatic life is an active, rather than a passive, biological process. Because the primary pathway for most metal uptake by aquatic life is through respiratory organs of fish and aquatic invertebrates, and only ionic forms of metals can pass through cell membranes, the toxicity of most metals to aquatic life is a function of the concentration of dissolved ionic forms of metals in the stream. Consequently, particulate metals are not directly toxic to most forms of aquatic life.

Many toxic substances, including metals, have a tendency to leave the dissolved phase and attach to suspended particulate matter. The fractions of total metal concentration present in the particulate and dissolved phases depend on the partitioning behavior of the metal ion and the concentration of suspended particulate matter. The dissolved fraction may also be affected by complexing of metals with organic binding agents. Idaho water quality standards are based on the bioavailable dissolved forms of metals.

Sediment

Both suspended (floating in the water column) and bedload (moves along the stream bottom) sediment can have negative effects on aquatic life communities. Many fish species can tolerate elevated suspended sediment levels for short periods of time, such as during natural spring runoff, but longer durations of exposure are detrimental. Elevated suspended sediment levels can interfere with feeding behavior (difficulty finding food due to visual impairment), damage gills, reduce growth rates, and in extreme cases eventually lead to death.

Newcombe and Jensen (1996) reported the effects of suspended sediment on fish, summarizing 80 published reports on streams and estuaries. For rainbow trout, physiological stress, which includes reduced feeding rate, is evident at suspended sediment concentrations of 50 to 100 mg/L when those concentrations are maintained for 14 to 60 days. Similar effects are observed for other species, although the data sets are less reliable. Adverse effects on habitat, especially spawning and rearing habitat presumably from sediment deposition, were noted at similar concentrations of suspended sediment.

Organic suspended materials can also settle to the bottom and, due to their high carbon content, lead to low intergravel DO through decomposition.

In addition to these direct effects on the habitat and spawning success of fish, detrimental changes to food sources may also occur. Aquatic insects, which serve as a primary food source for fish, are affected by excess sedimentation. Increased sedimentation leads to a macroinvertebrate community that is adapted to burrowing, thereby making the macroinvertebrates less available to fish. Community structure, specifically diversity, of the aquatic macroinvertebrate community is diminished due to the reduction of coarse substrate habitat.

Settleable solids are defined as the volume (milliliters [ml]) or weight (mg) of material that settles out of a liter of water in one hour (Franson et al. 1998). Settleable solids may consist of large silt, sand, and organic matter. Total suspended solids (TSS) are defined as the material collected by filtration through a 0.45 µm (micrometer) filter (Standard Methods 1975, 1995). Settleable solids and TSS both contain nutrients that are essential for aquatic plant growth. Settleable solids are not as nutrient rich as the smaller TSS, but they do affect river depth and substrate nutrient availability for macrophytes. In low flow situations, settleable solids can accumulate on a stream bottom, thus decreasing water depth. This increases the area of substrate that is exposed to light, facilitating additional macrophyte growth.

Stream siltation caused by silviculture activities and related road construction can be especially damaging to spawning gravels. The reduction of interstitial space between gravels can make it difficult for the incubation of eggs and the survival of juvenile trout.

Sediment-Temperature Relationship

In addition to reducing shading, activities that remove streamside vegetation reduce bank stability, causing accelerated bank erosion and increased sediment loading. Bank erosion and other sources of increased sedimentation result in wider and shallower streams, which increase the stream's heat load by increasing the surface area subject to solar radiation and heat exchange with the air. When addressing sediment pollution, it is useful to recognize the potential benefit to stream temperatures from these activities as well. Conversely, when addressing temperature pollution by increasing riparian vegetation, it is useful to recognize the additional benefits of stabilized banks and reduced erosion.

Bacteria

Escherichia coli or E. coli, a species of fecal coliform bacteria, is used by the state of Idaho as the indicator for the presence of pathogenic microorganisms. Pathogens are a small subset of microorganisms (e.g., certain bacteria, viruses, and protozoa), which, if taken into the body through contaminated water or food, can cause sickness or even death. Some pathogens are also able to cause illness by entering the body through the skin or mucous membranes.

Direct measurement of pathogen levels in surface water is difficult because pathogens usually occur in very low numbers and analysis methods are unreliable and expensive. Consequently, indicator bacteria which are often associated with pathogens, but which generally occur in higher concentrations and are thus more easily measured, are assessed.

Coliform bacteria are unicellular organisms found in feces of warm-blooded animals such as humans, domestic pets, livestock, and wildlife. Coliform bacteria are commonly monitored as part of point source discharge permits (National Pollution Discharge Elimination System [NPDES] permits), but may also be monitored in nonpoint source arenas. The human health effects from pathogenic coliform bacteria range from nausea, vomiting, and diarrhea to acute respiratory illness, meningitis, ulceration of the intestines, and even death. Coliform bacteria do not have a known effect on aquatic life.

Coliform bacteria from both point and nonpoint sources impact water bodies, although point sources are typically permitted and offer some level of bacteria-reducing treatment prior to discharge. Nonpoint sources of bacteria are diffuse and difficult to characterize. Unfortunately, nonpoint sources often have the greatest impact on bacteria concentrations in water bodies. This is particularly the case in urban storm water and agricultural areas. *E. coli* is often measured in colony forming units (cfu) per 100 ml.

Nutrients

While nutrients are a natural component of the aquatic ecosystem, natural cycles can be disrupted by increased nutrient inputs from human activities. The excess nutrients result in accelerated plant growth and can result in a eutrophic or enriched system.

The first step in identifying a water body's response to nutrient flux is to define which of the critical nutrients is limiting. A limiting nutrient is one that normally is in short supply relative to biological needs. The relative quantity affects the rate of production of aquatic biomass.

Either phosphorus or nitrogen may be the limiting factor for algal growth, although phosphorous is most commonly the limiting nutrient in Idaho waters. Ecologically speaking, a resource is considered limiting if the addition of that resource increases growth.

Total phosphorus (TP) is the measurement of all forms of phosphorus in a water sample, including all inorganic and organic particulate and soluble forms. In freshwater systems, typically greater than 90% of the TP present occurs in organic forms as cellular constituents in the biota or adsorbed to particulate materials (Wetzel 1983). The remainder of phosphorus is mainly soluble orthophosphate, a more biologically available form of phosphorus than TP that consequently leads to a more rapid growth of algae. In impaired systems, a larger percentage of the TP fraction is comprised of orthophosphate. The relative amount of each form measured can provide information on the potential for algal growth within the system.

Nitrogen may be a limiting factor at certain times if there is substantial depletion of nitrogen in sediments due to uptake by rooted macrophyte beds. In systems dominated by blue-green algae, nitrogen is not a limiting nutrient due to the algal ability to fix nitrogen at the water/air interface.

Total nitrogen to TP ratios greater than seven are indicative of a phosphorus-limited system while those ratios less than seven are indicative of a nitrogen-limited system. Only biologically available forms of the nutrients are used in the ratios because these are the forms that are used by the immediate aquatic community.

Nutrients primarily cycle between the water column and sediment through nutrient spiraling. Aquatic plants rapidly assimilate dissolved nutrients, particularly orthophosphate. If sufficient nutrients are available in stream sediments or the water column, aquatic plants will store an abundance of such nutrients in excess of the plants' actual needs; this is a chemical phenomenon known as luxury consumption. When a plant dies, the tissue decays in the water column and the nutrients stored within the plant biomass are either restored to the water column or the detritus becomes incorporated into the river sediment. As a result of this process, nutrients (including orthophosphate) that are initially released into the water column in a dissolved form will eventually become incorporated into the river bottom sediment. Once these nutrients are incorporated into the river sediment, they are available once again for uptake by yet another life cycle of rooted aquatic macrophytes and other aquatic plants. This cycle is known as nutrient spiraling. Nutrient spiraling results in the availability of nutrients for later plant growth in higher concentrations downstream.

Excess nutrient loading can be a water quality problem due to the direct relationship of high TP concentrations on excess algal growth within the water column, combined with the direct effect of the algal life cycle on DO and pH within aquatic systems. Therefore, the reduction of TP inputs to the system can act as a mechanism for water quality improvements, particularly in surface-water systems dominated by blue-green algae, which can acquire nitrogen directly from the atmosphere and the water column. Phosphorus management within these systems can potentially result in improvement in nutrients (phosphorus), nuisance algae, DO, and pH.

Sediment – Nutrient Relationship

The linkage between sediment and sediment-bound nutrients is important when dealing with nutrient enrichment problems in aquatic systems. Phosphorus is typically bound to particulate matter in aquatic systems and, thus, sediment can be a major source of phosphorus to rooted macrophytes and the water column. While most aquatic plants are able to absorb nutrients over the entire plant surface due to a thin cuticle (Denny 1980), bottom sediments serve as the primary nutrient source for most sub-stratum attached macrophytes. The USDA (1999) determined that other than harvesting and chemical treatment, the best and most efficient method of controlling growth is by reducing surface erosion and sedimentation.

Sediment acts as a nutrient sink under aerobic conditions. However, sediments release phosphorous into the water column when conditions become anoxic. Nitrogen can also be released, but the mechanism by which it happens is different. The exchange of nitrogen between sediment and the water column is for the most part a microbial process controlled by the amount of oxygen in the sediment. When conditions become anaerobic, the oxygenation of ammonia (nitrification) ceases and an abundance of ammonia is produced. This condition results in a reduction of nitrogen oxides (NO_x) being lost to the atmosphere.

Sediments can play an integral role in reducing the frequency and duration of phytoplankton blooms in standing waters and large rivers. In many cases there is an immediate response in phytoplankton biomass when external sources are reduced. In other cases, the response time is slower, often taking years. Nonetheless, the relationship is important and must be addressed in waters where phytoplankton is in excess.

Floating, Suspended, or Submerged Matter (Nuisance Algae)

Algae are an important part of the aquatic food chain. However, when elevated levels of algae impact beneficial uses, the algae are considered a nuisance aquatic growth. The excess growth of phytoplankton, periphyton, and/or macrophytes can adversely affect both aquatic life and recreational water uses. Algal blooms occur where adequate nutrients (nitrogen and/or phosphorus) are available to support growth. In addition to nutrient availability, flow rates, velocities, water temperatures, and penetration of sunlight in the water column all affect algae (and macrophyte) growth. Low velocity conditions allow algal concentrations to increase because physical removal by scouring and abrasion does not readily occur. Increases in temperature and sunlight penetration also result in increased algal growth. When the aforementioned conditions are appropriate and nutrient concentrations exceed the quantities needed to support normal algal growth, excessive blooms may develop.

Commonly, algae blooms appear as extensive layers or algal mats on the surface of the water. When present at excessive concentrations in the water column, blue-green algae often produce toxins that can result in skin irritation to swimmers and illness or even death in organisms ingesting the water. The toxic effect of blue-green algae is worse when an abundance of organisms die and accumulate in a central area.

Algal blooms also often create objectionable odors and coloration in water used for domestic drinking water and can produce intense coloration of both the water and shorelines as cells accumulate along the banks. In extreme cases, algal blooms can also result in impairment of agricultural water supplies due to toxicity. Water bodies with high nutrient concentrations that could potentially lead to a high level of algal growth are said to be eutrophic. The extent of the effect is dependent on both the type(s) of algae present and the size, extent, and timing of the bloom.

When algae die in low flow velocity areas, they sink slowly through the water column, eventually collecting on the bottom sediments. The biochemical processes that occur as the algae decompose remove oxygen from the surrounding water. Because most of the decomposition occurs within the lower levels of the water column, a large algal bloom can substantially deplete DO concentrations near the bottom. Low DO in these areas can lead to decreased fish habitat as fish will not frequent areas with low DO. Both living and dead (decomposing) algae can also affect the pH of the water due to the release of various acid and base compounds during respiration and photosynthesis. Additionally, low DO levels caused by decomposing organic matter can lead to changes in water chemistry and a release of sorbed phosphorus to the water column at the water/sediment interface.

2.4 Summary and Analysis of Existing Water Quality Data

Numerous sources of water quality data were used in this Subbasin Assessment and TMDL. DEQ monitoring (BURP) data were used as the baseline information. Several detailed studies of the Lightning Creek drainage, Forest Service information and Idaho Department of Lands Cumulative Effects Analyses were all used to summarize existing water quality in this section. Monthly and continuous water quality monitoring by the Tri-State Water Quality Council and the USGS were also used.

Data Sources

DEQ has collected Beneficial Use Reconnaissance Program (BURP) data on most of the larger streams in the subbasin. From 1994-2002, 33 BURP surveys were completed in the subbasin. Data sets reflected in BURP surveys include temperature, habitat, macroinvertebrate and fisheries information. Locations of BURP surveys are shown in Figure X. The USGS operates two gaging stations in the subbasin. Stream flow and water quality samples were taken intermittently at the mouth of Lightning Creek and below Cabinet Gorge dam on the Lower Clark Fork River. Water quality samples collected by the USGS and Land and Water Consulting Inc. from 1993-2003 are considered in the following analysis. Discharge has been gauged since 1928 on the Clark Fork River below the Cabinet Gorge dam and since 1988 on Lightning Creek near Clark Fork, Idaho. Eleven temperature data loggers have been deployed in the subbasin by the DEQ to constantly monitor water temperature during the hottest period of the year. (See Table X). In addition, where it was available, other watershed specific data were used.

Biological data available for examination include macroinvertebrate, fish, and habitat data collected through DEQ's Beneficial Use Reconnaissance Program (BURP). The data are arranged in indices and scored to determine if the water body in question is supporting its beneficial uses. Three indices are considered when making a beneficial use support status determination. The indices are classified by ecoregion. For all the indices, the entire Lower Clark Fork River is considered to be located in the Northern Mountains ecoregion.

The first index is the Stream Macroinvertebrate Index (SMI). By recording the abundance of macroinvertebrates known to live only in specific temperature conditions, the index is used as a direct biological measure of cold water aquatic life (Grafe et al. 2002). A detailed description of this index can be found in Jessup and Gerritsen (2000). A high score (three) on the index indicates a healthy assemblage of species close to reference condition streams in the state.

The second index is the Stream Fish Index (SFI). This index is also considered a direct biological measure of cold water aquatic life and is used to determine how close the stream is to achieving the Clean Water Act "fishable" goal. The details of the development of this index can be found in Mebane (2002). Mebane developed this index based on least impacted and stressed sites. Fish counts are taken in each watershed and the index relates data found to known index, or reference sites.

The last index considered when determining beneficial use support is the Stream Habitat Index (SHI). Details of this index can be found in Fore and Bollman (2000). The habitat index considers ten habitat metrics such as: instream cover, substrate composition, bank and canopy cover and zone of influence. SHI is not considered to be a direct biological measure, therefore it is recommended that it always be used in conjunction with at least one other index. This is due to significant variability in physical habitat measures (Grafe et al. 2002). Metrics tailored to forested areas were used for the SHI.

Each index uses a scale of one to three. The values resulting from each index are averaged to determine the support status of each waterbody as described in DEQ's Water Body Assessment Guidance, Second Edition (Grafe et al. 2002). A score of three indicates the stream is most likely to fully support beneficial uses. Average values of two or greater indicate a waterbody that is in full support of its beneficial uses. Scores of less than two indicate that the waterbody in question is not supporting its beneficial uses. Scores from at least two indices are required to make a support status determination. If either the macroinvertebrate or fish score is zero, the waterbody is considered to not fully support beneficial uses. Available index scores for the Lower Clark Fork River can be found in Appendix X. The beneficial use support status for each waterbody in the subbasin is presented in Tables X-X.

In addition to BURP data, other sources of water quality data were compiled and summarized to give a snapshot of water quality in the subbasin. A detailed watershed analysis report for Lightning Creek and its tributaries was completed in 2004 by Philip Williams and Associates, Limited, with consultation from land and resource management agencies (referred to as PWA 2004 throughout the document). The report includes extensive field surveys, especially regarding road condition and mass wasting potential, and it summarizes existing data on the area. The report is extensive and while summary results are used to inform this analysis of water quality, there is a wealth of additional information. The report includes both an overview of watershed health and an implementation plan that prioritizes restoration opportunities in the Lightning Creek watershed. The reader is encouraged to review the *Lightning Creek Watershed Assessment* for additional information on that portion of the subbasin and to use this report as a basis for TMDL implementation.

In addition to the Lightning Creek Watershed Assessment mentioned above, there are other documents and research funded by Avista Utilities as part of the federal relicensing process and the on-going settlement agreement to mitigate the impacts of its hydropower operations in the subbasin. A virtual library of information on fisheries and water quality status were compiled during the relicensing process in the 1990s, and over the last five-years additional monitoring and research reports have been compiled, especially in relation to impacts of hydropower development and native aquatic species restoration opportunities. Where applicable, these data are incorporated in this analysis as well.

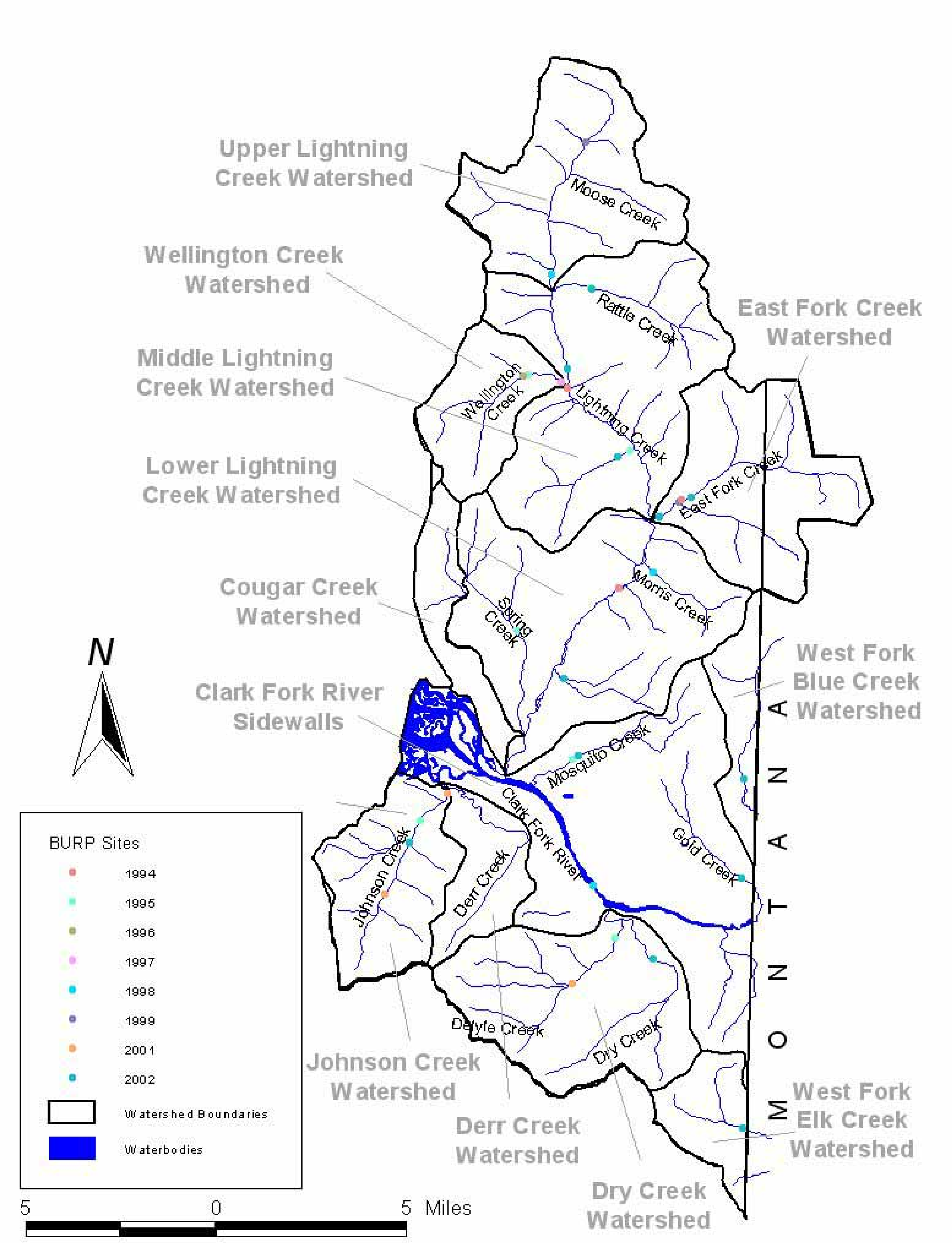


Figure X. Locations of BURP monitoring sites, 1994-2002.

The following section summarizes existing water quality data from BURP and other sources, used to determine the status of beneficial uses for each subwatershed in the basin.

Flow Characteristics

Flow characteristics are available for the Clark Fork River and Lightning Creek.

Clark Fork River

The mainstem Clark Fork River from Cabinet Gorge dam flows for about nine miles before it enters Lake Pend Oreille. In addition to the main channel, there is a side channel that starts at Foster Rapids and the river delta area, including Mosquito Creek. Unless otherwise noted, the information presented below pertains to the mainstem.

Due to the significantly altered flow regime from hydropower operations, all three mainstem AUs of the Clark Fork River in Idaho are considered impaired by flow alteration.

Stream flow data is collected by the USGS on the Clark Fork River below the Cabinet Gorge Dam. Data collected at this station was also recorded under the name Whitehorse Rapids gaging station (O'Dell, pers comm). Data collected at this station represent flow conditions in 22,073 mi^2 of the watershed, the majority of which lies in Montana. Recording of data began in 1929. Mean annual runoff recorded at the station below the Cabinet Gorge Dam, through water year 2001, is 22,548 cfs.

The main river flows are influenced by the hydropower operation at Cabinet Gorge Dam. Under the current Clark Fork River Settlement Agreement, minimum flows will not be below 5,000 cfs.

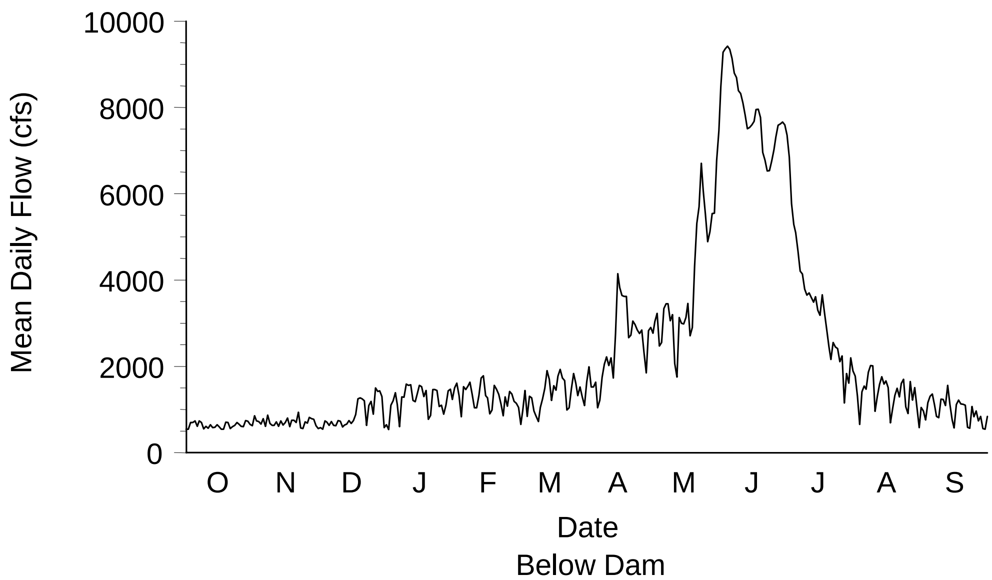


Figure X. Mean Daily Flow of the Clark Fork River at USGS Gaging Station Below the Cabinet Gorge Dam.

Annual runoff in the Clark Fork River is produced mostly by melting snow, with peak flows typically occurring in May or June, but occasionally in April or July. Midwinter rain on snow events can result in a rapid snowmelt, and in some years, peak flow from tributary watersheds occurs during these events. Due to the effects of high precipitation, location in relation to Lake Pend Oreille, prevailing winds, and the tendency for warm winter storms to pick up moisture from the lake, Lightning Creek and other tributaries draining the Cabinet Mountains are particularly susceptible to rain on snow events.

Lightning Creek

Flows in the Lightning Creek watershed are driven by heavy seasonal variation in precipitation, and high flows often occur at times of rain on snow event. A USGS station is located on Lightning Creek at the city of Clark Fork. This station records data from 115.2 mi^2 of watershed. Data have been recorded at Lightning Creek since 1989. Mean annual runoff at the Lightning Creek gaging station, through water year 2001, is 411 cfs.

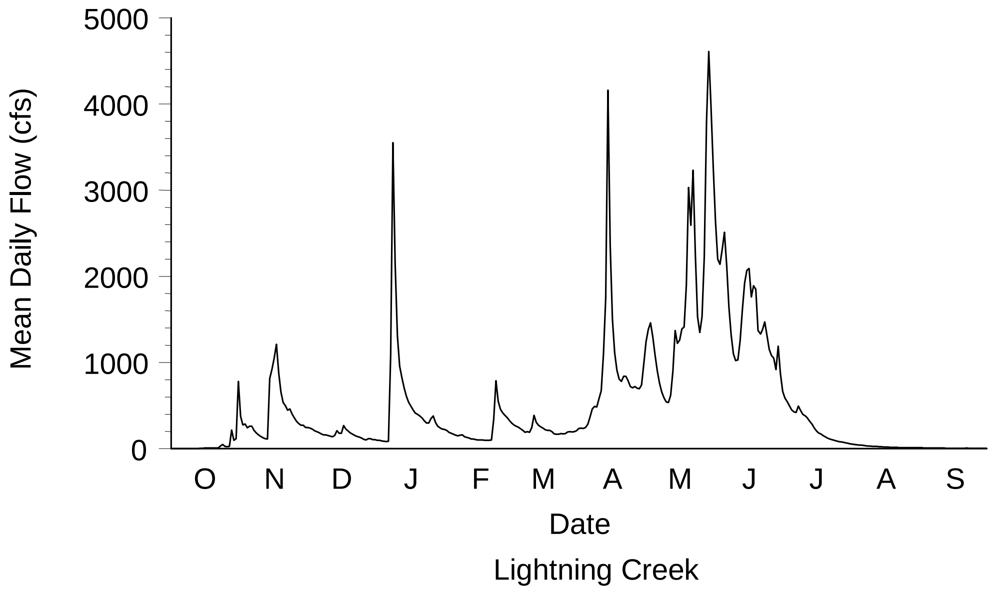


Figure X. Mean Daily Flow of Lightning at USGS Gaging Station near Clark Fork, Idaho.

Water Column Data

Water column data are collected by the USGS below Cabinet Gorge dam and on Lightning Creek. BURP samples included bacteria testing, and no exceedences of bacteria standards were found.

Clark Fork River

Water column data collected below Cabinet Gorge dam from 1998-2002 are presented in Table X. Nutrients and pH levels were within Idaho Water Quality Standards, but temperatures above the standard for Salmonid Spawning were recorded.

General water quality information collected during the Clark Fork Project relicensing process includes water temperatures and information on total dissolved gas concentrations above and below the Cabinet Gorge Dam. Under the NPDES permit, discharge from the dam is monitored as well.

Lower Lightning Creek

Periodic data were collected in the water column at the USG S gaging station. These data are presented in Table X. All nutrient parameters measured were found to be within Idaho state WQS. Temperature data available from the USGS gaging station in addition to data collected during the Clark Fork River relicensing by Avista Utilities indicate temperature exceedences in the Lightning Creek.

Table X. Water Quality of the Lower Clark Fork River at the USGS Gaging Station Below the Cabinet Gorge Dam

Date	Temperature (degrees Celcius)	Instantaneous Discharge (cubic feet per second)	Specific Conductance (microsiemens per centimeter)	pH (standard units)	Ammonia (mg/L as N)	Ammonia + Organic Nitrogen (mg/L as N)	Nitrate + Nitrite (mg/L as N)	Phosphorus (mg/L)	Ortho-phosphate (mg/L as P)
WQS									
4/14/98	7.5	27,500	188	7.5	0.06	0.12	0.06	0.01	0.01
5/27/98	12	45,400	140	7.6	≤.02	3.3	0.06	≤.01	≤.01
6/24/98	14.9	52,000	163	7.9	0.12	≤.10	≤.05	≤.01	≤.01
7/16/98	19.3	33,800	172	7.7	0.04	0.15	0.05	0.02	0.02
8/4/98	22.8	33,300	183	8.3	0.05	0.15	0.07	≤.01	≤.01
9/1/98	20.8	3,500	192	8.3	0.02	0.2	≤.05	0.01	≤.01
4/8/99	6.2	30,500	179	7.7	0.003	0.14	0.035	0.011	0.003
5/12/99	9.1	34,000	156	7.5	0.003	0.14	0.023	0.01	0.001
6/11/99	11.1	54,400	128	7.8	0.007	0.12	0.037	0.02	0.004
7/21/99	17.3	31,000	158	8.1	≤.002	0.16	0.006	0.007	0.001
8/23/99	19.7	36,700	180	8.2	0.004	0.15	0.01	0.021	≤.001
9/14/99	17.1	5,430	188	8.1	≤.002	0.12	0.013	0.01	≤.001
4/4/00	6	30,500	192	8.2	≤.002	.06[1]	0.026	.004[1]	0.003
5/9/00	10.2	34,800	147	7.9	0.005	0.14	0.032	.004[1]	≤.001
5/23/00	12.5	35,100	151	8					
5/24/00	12	35,100	151	7.9					
5/24/00	12.5	47,000	151	8					
5/24/00	13	54,600	150	8					
5/25/00	12	35,000	148	7.9					
6/19/00	14.6	48,000	142	7.5	0.002	0.1	0.014	0.01	≤.001
7/7/00	17.5	31,100	162	8	0.002	0.11	0.01	.007[1]	0.002
8/7/00	22.2	21,300	173	8.1					
8/31/00	17.8	5,750	183	8					
9/5/00	17.9	8,230	184	8	0.006	.09[1]	0.03	0.008	0.002
10/25/00	10.8	20,700	196	8.2					

11/20/00	8.5	21,100	191	8.1					
12/20/00	1	22,900	198	7.8					
1/16/01	2.5	22,200	194	7.8					
3/1/01	4	18,400	196	7.7					
3/22/01	6	8,080	210	7.9					
4/5/01	5.6	8,110	211	8.6	0.01	0.1	0.043	0.005	≤.007
5/23/01	12	30,900	137	7.8	≤.002	0.11	0.026	0.018	≤.007
6/28/01	15.8	30,400	165	8.1	0.006	0.17	0.008	0.017	≤.007
7/26/01	19.8	6,330	179	8.2	0.002	0.11	0.009	0.006	≤.007
8/30/01	19.6	5,520	191	8.1	.008[1]	0.25	.014[1]	0.038	≤.007
9/25/01	17.1	5,440	201	8.2	0.008	0.14	0.021	0.017	≤.007
4/3/02	3	22,800	173	8	≤.015	.08[1]	0.041	0.005	≤.007
5/3/02	8.5	36,700	152	7.9	≤.015	0.14	0.04	0.015	≤.007
6/4/02	11.3	94,400	116	7.4	.013[1]	0.18	0.044	0.029	≤.007

[1]Estimated value

Table X. Water Quality of Lightning Creek at the USGS Gaging Station on Lightning Creek.

Date	Temperature (degrees Celcius)	Instantaneous Discharge (cubic feet per second)	Specific Conductance (microsiemens per centimeter)	pH (standard units)	Ammonia (mg/L as N)	Ammonia + Organic Nitrogen (mg/L as N)	Nitrate + Nitrite (mg/L as N)	Phosphorus (mg/L)	Orthophosphate (mg/L as P)
WQS									
7/29/98	17.3		21	6.5					
7/29/98									
7/29/99	25	218		6.8	0.002	.10[1]		≤.004	
8/2/99	12.7	175	15	7					
9/2/99	10	42		7.1	≤.002	.10[1]		0.004	0.001
10/26/99	8.2	97	24	7.5	0.005	.06[1]	0.086	≤.008	≤.001
3/2/00	2.9	183	32	7.2	0.004	≤.10	0.094	≤.008	0.003
3/30/00	2.7	314	26	7.3	≤.002	≤.10	0.112	≤.008	0.003
4/12/00	4.6	1030	19	7.3	0.005	.07[1]	0.207	≤.008	≤.001
5/4/00	4.4	2120	14	6.9	≤.002	.06[1]	0.211	.004[1]	≤.001
6/5/00	6.1	1810	12	6.8	≤.002	0.19	0.107	≤.008	≤.001
6/30/00	9.3	518	15	6.7	≤.002	.07[1]	0.042	≤.008	0.001
7/27/00	13.8	69	25	7.1	0.008	0.13	0.029	≤.008	0.001
9/1/00	9.2	7.1	26	7.4	0.006	≤.10	0.025	≤.008	≤.001
11/9/00	6.1	30	27	6.9	≤.002	≤.08	0.083	≤.004	≤.007
12/14/00	4.3	6.6	26	6.6	0.024	≤.08	0.114	≤.004	≤.007
1/25/01	4.8	7.4	27	7.3	≤.002	≤.08	0.156	.002[1]	≤.007
3/15/01	4	43	31	7.3	0.003	≤.08	0.162	.003[1]	≤.007
4/11/01	3.7	139	36	7	0.002	.06[1]	0.14	.002[1]	≤.007
5/4/01	7.4	595	21	7.1	≤.002	.08[1]	0.247	≤.004	≤.007
6/14/01	7.2	821	16	7.2	0.003	.06[1]	0.072	0.004	≤.007

[1] Estimated Value

Temperature

Nine temperature data logger data sets have been collected in the Idaho portions of the Lower Clark Fork River basin. Data were collected during the warmest summer months thru fall spawning periods. Data were collected during this time to identify periods of critical temperature criteria exceedences. All data recorded are in exceedence of Idaho water quality standard temperature criteria for fall salmonid spawning and one temperature data logger site (2001) on Lower Lightning Creek, .5 miles downstream of Morris Creek confluence, was also in exceedence of cold water aquatic biota criteria.

The following table outlines the number of days evaluated for cold water aquatic biota criteria, bull trout fall spawning 9ºC temperature criteria and the percent exceedence of each.

Table X. Temperature criteria exceedences in the Idaho portion of the Lower Clark Fork HUC.

Stream name and Temperature Logger site ID	Cold Water Aquatic Biota Criteria		Fall Salmonid Spawning 9ºC Criteria		
	Days evaluated within dates	*% Exceedence*	*Days evaluated within window*	*% Exceedence*	*Duration of Deployment*
Char Creek 1998SCDATL0011	67	0	76	61%	07/18/1998-11/11/1998
Porcupine Creek 1998SCDATL0013	67	0	76	83%	07/18/1998-11/11/1998
Rattle Creek 1998SCDATL0014	67	0	76	70%	07/18/1998-11/11/1998
Quartz Creek 1998SCDATL0015	67	0	76	63%	07/18/1998-11/08/1998
Wellington Creek 1998SCDATL0016	67	0	76	68%	07/18/1998-11/11/1998
Lightning Creek 1999SCDATL0032	68	0	57	49%	07/17/1999-09/26/1999
Morris Creek 1999SCDATL0038	68	0	76	70%	07/17/1999-10/17/1999
Johnson Creek 2001SCDATL0028	94	0	72	92%	06/20/2001-10/11/2001

Lightning Creek 2001SCDATL0042	81	20%	40	100%	06/21/2001-09/09/2001

Dissolved Oxygen

No exceedences of the dissolved oxygen criteria were found in the Lower Clark Fork River or Lightning Creek. These are the only areas of the subbasin where DO information were available.

Total Dissolved Gas

All three mainstem Clark Fork River Assessment Units show an exceedence of Total Dissolved Gas (TDG) levels.

Since 1995, Total Dissolved Gas below Cabinet Gorge Dam has been monitoring during spring runoff periods (generally April – July). Below Cabinet Gorge Dam, peak hourly TDG levels were frequently 125-130% saturation in June. In 2002, levels exceeded 130% about 16% of the time. Because of frequent exceedences of the 110% saturation standard during peak flows, there is on-going total dissolved gas monitoring and a mitigation plan in place. Details are available in *The Gas Supersaturation Control Program for the Cabinet Gorge and Noxon Rapids Hydroelectric Projects* (Avista 2004) as approved by the DEQ as a part of the required water quality certification for the project operations and federal license.

In the assessment unit above Cabinet Gorge Dam, TDG levels frequently reach 110-111% saturation during peak flows, violating Idaho water quality standards (Parametrix 1995-2004). At these same times, TDG is measured at the Noxon Rapids dam, and typically, the TDG levels are slightly lower at the Cabinet Gorge forebay area than at the Noxon Rapids forebay. This indicates that waters with elevated TDG are entering Idaho, with the source above Noxon Rapids dam. In order to fully address elevated TDG levels, especially at the critical peak flow times, reductions in TDG levels of the waters entering Idaho are necessary in addition to the extensive mitigation plan in place for below Cabinet Gorge dam.

Metals

Idaho's metals criteria are based on the bioavailable dissolved form of metals found in the water column. These numeric standards set to be protective of aquatic life. The toxicity of metals is directly related to the water's hardness[3], therefore, to determine Idaho's metals standards for a particular waterbody, a calculation that relates the hardness value at the time of the sampling is used. Water Quality Standards are expressed as both an acute value, Criterion Maximum Concentration (CMC), and a chronic value, Criterion Continuous Concentration (CCC). Per Idaho's water quality standards, the one-hour average concentration of a constituent is not to exceed the CMC more than once every

[3] Hardness is a calculated value based on measured calcium and magnesium levels in the water at the USGS gaging station below Cabinet Gorge dam.

three years, while the four-day average concentration of a constituent is not to exceed CCC more than once every three years. Due to the limited number of metals samples available for analysis, DEQ was not able to calculate one-hour and four-day average concentrations. Therefore, single sample values were used to determine whether the CCC and CMC standards were being met.

Monitoring data for metals are available for Lightning Creek and the Lower Clark Fork River.

Lightning Creek

USGS sampled the water column for arsenic, cadmium, copper, lead, mercury, and other trace metals at the Lightning Creek gaging station between 1999 and 2001. No exceedences of water quality standards in Lightning Creek were found.

Clark Fork River

The main stem of the Clark Fork River was added to the Idaho 303(d) list in 1994 and this listing has carried over to current lists. There are no known significant sources of metals pollution to the Lower Clark Fork subbasin in Idaho. The source of metals contamination is historic activities in the Upper Clark Fork River basin.

Metals monitoring has been ongoing in the Clark Fork River at the USGS gaging station below the Cabinet Gorge dam. Samples below the dam were collected by Land and Water Consulting, Inc. for the Tri State Water Quality Council and by the USGS. The results of samples dating from 1988 through 2003 were analyzed for this TMDL. Constituents analyzed include arsenic, cadmium, chromium, copper, lead, mercury, silver, and zinc.

The following figures W, X, Y, Z present available data for copper, zinc, cadmium and lead and the applicable water quality standard based upon hardness. Where hardness measures are not available, the minimum hardness value measured in the area was used.

Within the last fifteen years, exceedences of the acute criteria (CCC) have occurred for cadmium (1991), and copper (1992, 1996). Exceedences of the chronic criteria (CMC) for cadmium (1990, 2003), copper (1992, 1996) and zinc (2003) have also occurred.

There was one exceedence of the lead CMC and two CCC in 1992. No exceedences have been measured since that time, however, limited data are available regarding lead levels as the USGS stopped sampling lead at this site in 1994. The Tri-State Water Quality Council sampled for lead below Cabinet Gorge dam in 2004 and in only one sample (n = 18 for the year), was lead detected, and it was measured right at the detection lime (.001 mg/l). While limited, recent available data indicate that lead levels do not exceed water quality standards. Therefore, no TMDL will be developed for lead. Also, it is assumed that by developing TMDLs for the other metals, lead levels will also be controlled. Lead will continue to be monitored by the Tri-State Water Quality Council, and a TMDL will be developed in the future if lead levels are found to be in exceedence of Idaho Water Quality Standards.

In 1993, there was an exceedence of the total recoverable mercury standard, however, the detection limit was equal to the exceedence level, making measurement difficult. The last mercury sample taken was in 1994. Some studies have been done in the area to assess the level of mercury in fish. In 1986, Barnard and Vashro determined that bioaccumulation of copper and mercury was comparable to other non-contaminated waters elsewhere in the region. They found elevated levels of zinc (55 to 166 ppm) in the 68 fish sampled. In 1993, a limited study of fish tissue indicated that mercury levels were high in pike minnow and that further research was necessary. In 2005, a mercury advisory was issued on Lake Pend Oreille based on fish tissue analysis by Idaho Fish and Game in Lake Pend Oreille. Montana Fish Wildlife and Parks completed a fish tissue analysis of fish in Cabinet Gorge reservoir in 2005 and found __________. Recent studies have shown that sources of mercury are prevalent in the atmosphere throughout the United States and may be difficult to pinpoint. Standards are currently undergoing revision in the state of Idaho. It is likely that future monitoring will occur to determine the accumulated level of mercury in area fish, as well as potential contributions from atmospheric sources of mercury. When data are available, the Clark Fork River should be re-evaluated for potential mercury issues.

Table X. Idaho Water Quality Standards at the minimum measured hardness level. Standards were calculated using hardness based conversion formula outlined in IDAPA 58.01.02.210.02.

	CMC (ug/l)	CCC (ug/l)
Arsenic		
Cadmium	1.3	.74
Chromium III	395	51
Chromium IV	15	10
Copper	11.2	7.8
Lead	40	1.54
Mercury	Fish tissue based standard	
Nickel	321	36
Silver	1.6	NA
Zinc	80	81

[1] Minimum Value = 64 mg/l. Calculated from USGS calcium and magnesium values below the Cabinet Gorge Dam.
[2]Criterion Maximum Concentration
[3]Criterion Continuous Concentration

Figure X: Existing Lower Clark Fork River Water Column Copper Sample Data.

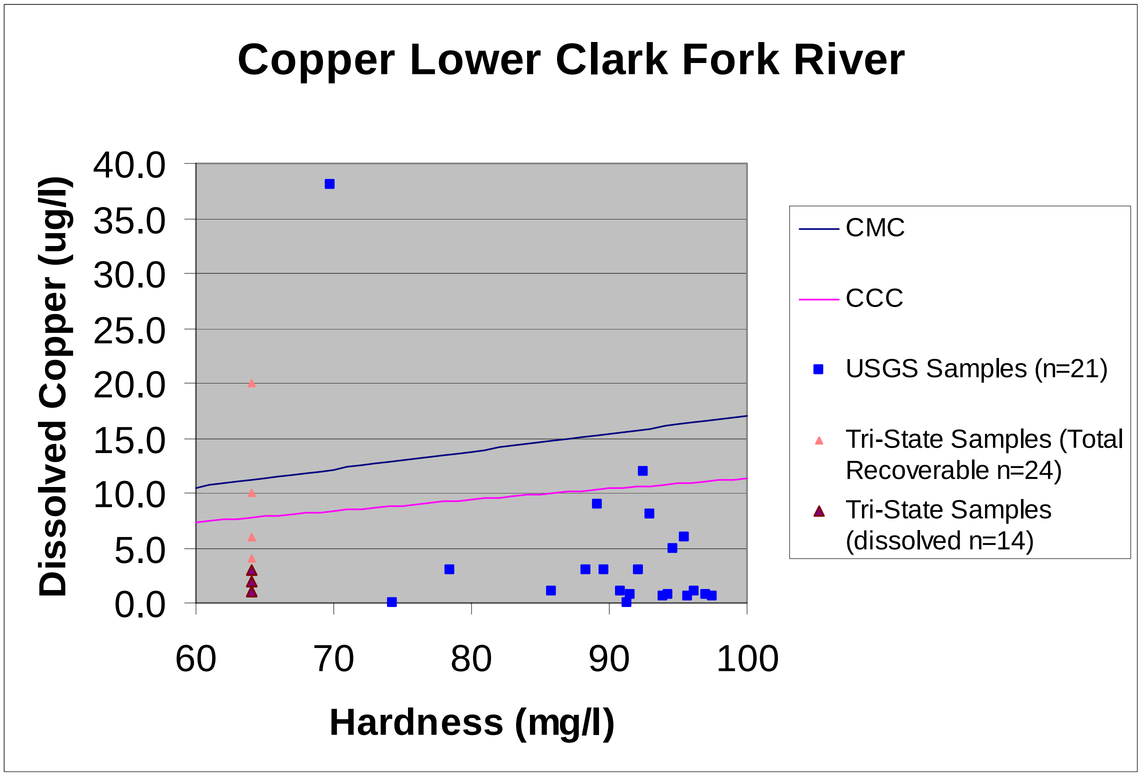


Figure X: Existing Water Column Zinc Sample Data 1989-2003.

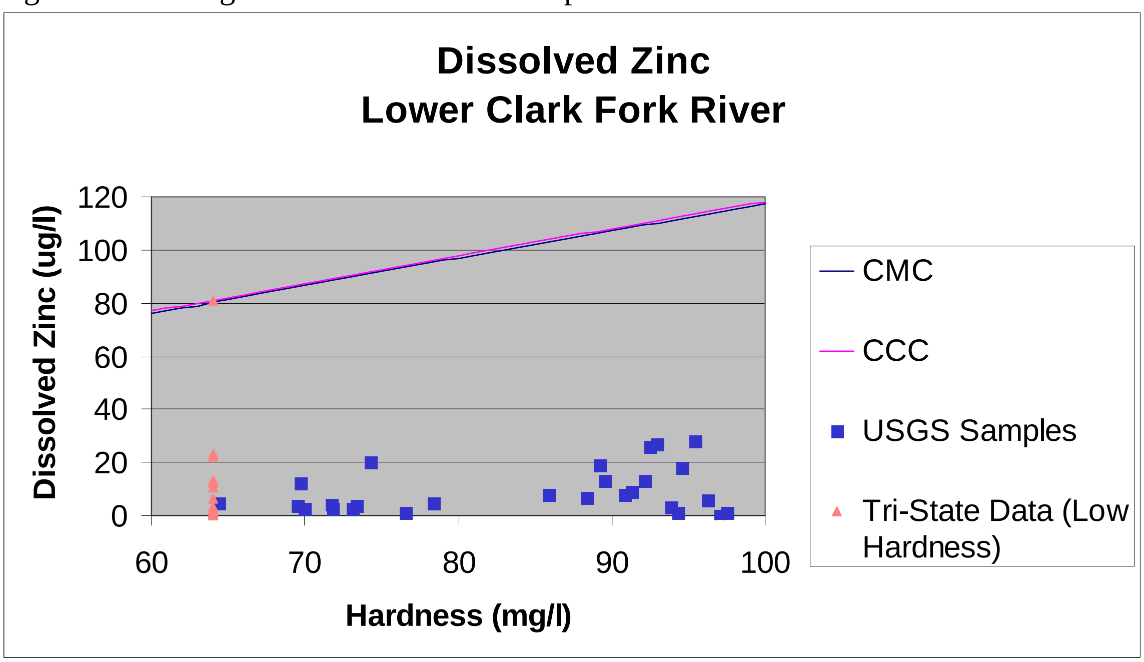


Figure W: Existing Water Column Cadmium Sample Data 1989-2003.

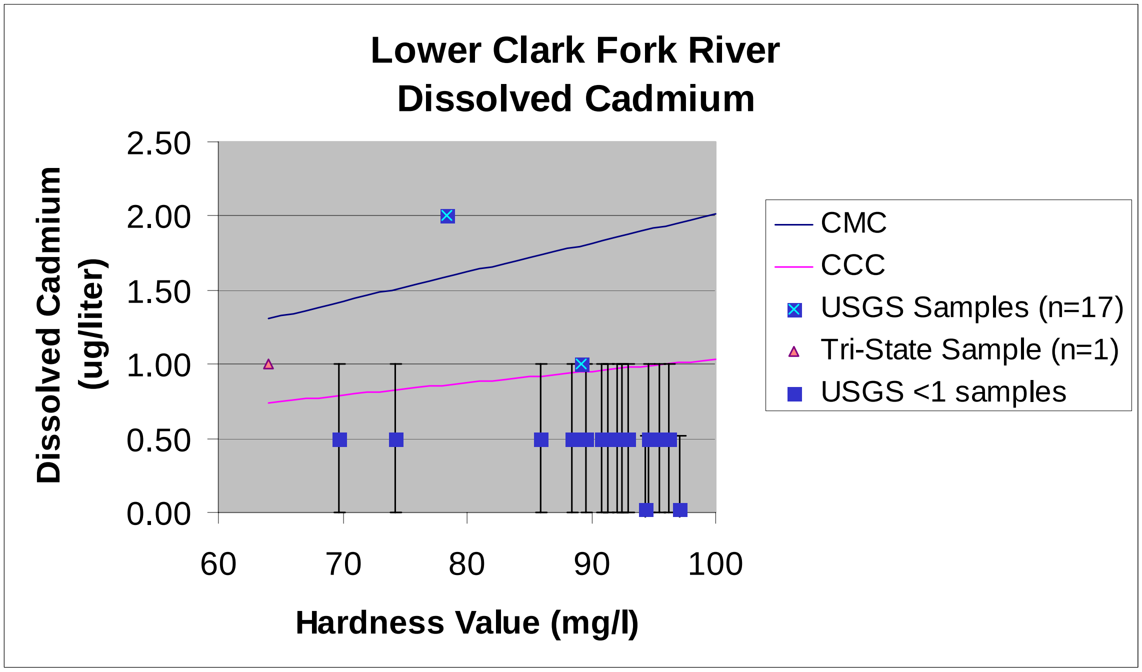
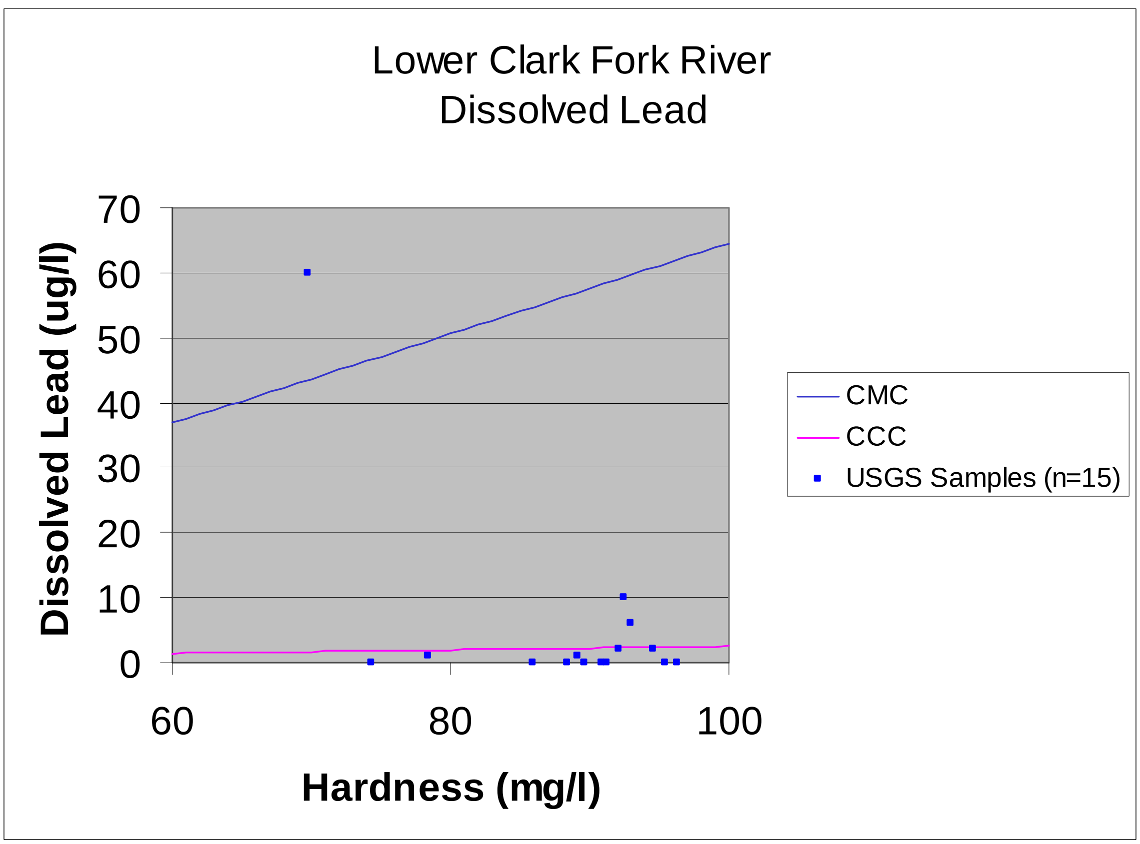


Figure Y: Existing Water Column Lead Sample Data to 1995.



Biological and Other Data

Lower Clark Fork

The Lower Clark Fork is an eighth order river by the time it enters Idaho. As such, the BURP monitoring methods are not appropriate. No macroinvertebrate data are available from Idaho DEQ sampling. However, there is extensive fisheries information and other indicators of the biological status of the river from other sources. Since the construction of the Cabinet Gorge and other hydropower facilities, native fish populations have been declining in the area.

The Bull Trout Problem Assessment ranks the Clark Fork River as a high priority for bull trout restoration. The largest impact to bull trout and other fisheries populations comes from the Cabinet Gorge dam upstream of the Lake and Albeni Falls dam downstream of the Lake. Impacts include loss of access to upstream habitat, artificially high lake levels, fluctuating flows and total dissolved gas levels that are in exceedance of Idaho WQS the majority of the time. Delta conditions have been altered over time by operation of Albeni Falls and Cabinet Gorge projects, increasing erosion and decreasing sediments from upstream (PBTTAT 1998).

When constructed, the Cabinet Gorge Dam cut off access to 46 percent of bull trout spawning and rearing habitat available at the time of construction. (the earlier construction of Thompson Falls dam cut off a much larger portion of the habitat in the early 1900s). Current efforts through the Clark Fork Settlement Agreement studied possible fish passage methods, and “trap and haul” operations are being tested and developed to move fish upstream and downstream of Noxon Rapids and Cabinet Gorge dams (Implementation Plan 2004).

Recent studies by Avista in coordination with resource and regulatory agencies have explored the impacts of Total Dissolved Gas supersaturation on fisheries populations. While it is clear there is some displacement, there is still some question as to the extent of impact the increased gas levels have on fish populations in the river. It is known that levels above 110 percent saturation, the current Idaho WQS, can be detrimental to fish populations and fish exposed to high total dissolved gas levels for extended periods of time can be harmed or killed (PBTTAT 1998).

Lightning Creek

Biological data are available for those streams assessed by BURP crews, with index scores presented in Table X.

Macroinvertebrate sampling was done at several BURP sites on mainstem Lightning Creek and its tributaries (Figure X). Relatively healthy populations of cold water specific macroinvertebrates were found in the samples. BURP sampling was done in 1994, 1995, 1998 and 2002 on the mainstem and throughout the tributaries.

Table X. BURP Sites and Index Scores for Lower Clark Fork River subwatersheds.

STREAM NAME	BURP Site ID	Stream Macro-invertebrate Index (SMI)	Stream Fish Index (SFI)	Stream Habitat Index (SHI)
CASCADE CREEK	2002SCDAA027	41.27	47.17	59
E FORK LIGHTING	1994SCDAA024	39.32	89.43	30
EAST FORK CREEK	2002SCDAA012	51.45	85.51	74
EAST FORK CREEK	2002SCDAA013	49.37	89.76	77
GOLD CREEK	2002SCDAA054	NA	NA	NA
JOHNSON CREEK	2002SCDAA025	NA	NA	NA
JOHNSON CREEK (LOWER)	2001SCDAA049	58.93	78.62	68
JOHNSON CREEK (LOWER)	1995SCDAA019	38.12	NA	NA
JOHNSON CREEK (UPPER)	2001SCDAA048	NA	NA	NA
JOHNSON CREEK (UPPER)	1995SCDAA020	27.01	NA	60
LIGHTING (LOWER R)	1994SCDAA023	NA	NA	41
LIGHTING CREEK	1994SCDAA025	69.43	NA	41
LIGHTNING CREEK (ABOVE QUARTZ CREEK)	1999SCDAA009	47.78	70.79	80
LIGHTNING CREEK (UPPER E FORK)	1995SCDAB025	69.43	NA	NA
LIGHTNING CREEK (UPPER)	1998SCDAA013	63.51	NA	69
LIGTHNING CREEK -mid	2002SCDAA026	NA	NA	
MORRIS CREEK	1998SCDAA014	50.61	97.7	71
MOSQUITO CREEK	2002SCDAA028	70	42.83	63
MOSQUITO CREEK	1995SCDAA053	46.08	NA	30
PORCUPINE CREEK	2002SCDAA015	57.28	83.66	75
PORCUPINE CREEK (LOWER)	1995SCDAA021	68.01	NA	58
RATTLE CREEK	2002SCDAA014	56.72	85.26	78
RATTLE CREEK	1995SCDAB019	56.48	NA	44
SAVAGE CREEK	1999SCDAA008	49.06	NA	85
SPRING CREEK (UPPER)	1995SCDAB012	54.98	NA	45
TWIN CREEK	2001SCDAA050	66.46	80.62	81
TWIN CREEK (LOWER)	1995SCDAA055	45.51	51.62	59
DRY CREEK	2002SCDAA024	NA	NA	NA
WELLINGTON CREEK	1996SCDAB033	49.07	NA	71
WELLINGTON CREEK	1995SCDAB017	67.87	NA	52
WELLINGTON CREEK(BELOW FALLS)	1997SCDAA041	NA	NA	67
WEST FORK BLUE CREEK	2002SCDAA055	NA	NA	NA
WEST FORK ELK CREEK	2002SCDAA023	NA	NA	NA

Table X. SMI, SFI and SHI scoring criteria.

Condition Category	SMI (Northern Mountains)	SFI (Forest)	SHI (Northern Rockies)	Condition Rating
Above the 25th percentile of reference condition	≥65	≥81	≥66	3
10th to 25th percentile of reference condition	57-64	67-80	58-65	2
Minimum to 10th percentile of reference condition	39-56	34-66	<58	1
Below minimum of reference condition	<39	<34		Minimum Threshold

Scoring criteria are based upon known values of streams in Idaho that are considered to be functioning, or reference condition streams. A condition rating of three indicates that the index values do not significantly differ from index scores of reference streams. Condition ratings of two or one do significantly vary from index scores associated with reference conditions, however a condition rating of two is considered likely to still support beneficial uses (Grafe et al. 2002).

Waterbody	BURP Site ID Number	Species	Number	Bull trout fish/m2/hr effort	Total Fish/m2/hr/effort	YOY?	Frogs/Salamanders
East Fork Creek	1994SCDAA024	rainbow trout	3		0.006	Yes	Not noted
		cutthroat trout	3				
		brook trout	1	0.004			
		bull trout	3				
		slimy sculpin	3				
		cutthroat trout (all stocks) x rainbow trout	2				
Johnson Creek	1995SCDAA019	cutthroat trout	2		0.011	Not noted	Not noted
		bull trout	2				
		slimy sculpin	2	0.005			
		cutthroat trout (all stocks) x rainbow trout	1				
		rainbow trout	1				
		brown trout	1				
Twin Creek	1995SCDAA055	rainbow trout	3		0.017	Not noted	Not noted
		brook trout	3	0.017			
		cutthroat trout (all stocks) x rainbow trout	2				
		bull trout	1				
Morris Creek	1998SCDAA014	rainbow trout	2		0.013	Not noted	Not noted
		cutthroat trout	2				
		brook trout	1				

		bull trout	2	0.012			
		trout	1				
		cutthroat trout (all stocks) x rainbow trout	1				
Lightning Creek	1999SCDAA009	cutthroat trout	1		0.01	Not noted	None observed
		brook trout	1				
Johnson Creek	2001SCDAA049	bull trout	1	0.005	0.021	Yes	None observed
		sculpin	1				
Twin Creek	2001SCDAA050	cutthroat trout	1		0.029	Not noted	Tailed Frog Tadpoles
		brook trout	1				
East Fork Creek	2002SCDAA012	cutthroat trout	10		0.071	Not noted	Not noted
East Fork Creek	2002SCDAA013	cutthroat trout	48	0.007	0.170	Not noted	Not noted
		bull trout	2				
Rattle Creek	2002SCDAA014	rainbow trout	4			Not noted	Not noted
		cutthroat trout	3	0.082	0.130		
		bull trout	12				
Porcupine Creek	2002SCDAA015	cutthroat trout	8		0.090	Not noted	Tailed Frog Tadpoles
		bull trout	2	0.018			
Lightning Creek -mid	2002SCDAA026	bull trout	1	0.002	0.018	Not noted	Not noted
		rainbow trout	7				
Cascade Creek	2002SCDAA027	rainbow trout	11		0.664	Not noted	Not noted

		brook trout	4				
Mosquito Creek	2002SCDAA028	brook trout	19		0.562	Not noted	Not noted

Table X. Fish presence data from BURP surveys.

IDFG has completed redd counts for bull trout in the Lower Clark Fork River subbasin. The trend has generally been a reduction in counts, with the last several years have stabilized counts (IDFG year). Redd counts are one of the best tools for estimating overall population status and these data were used as an indication of lack of full support of salmonid spawning in the Lightning Creek drainage when IDEQ kept Lightning Creek AUs listed as impaired in the 2002 integrated report.

The Lower Clark Fork River assessment units are considered impaired by habitat alteration. Delta conditions have been altered over time by operation of Albeni Falls and Cabinet Gorge projects, increasing erosion and decreasing sediments from upstream (PBTTAT 1998). At the second vehicle bridge (no longer used), varying lake levels begin to impact the water velocities, depth and hydrologic conditions of the river channel and delta (PBTTAT 1998).

A spawning channel created in the early 1960s as mitigation for impacts of Cabinet Gorge Dam continues to provide spawning and rearing habitat, though the number of bull trout redds has declined over the years (citation).

Summary tables of water quality data used to inform TMDL appear below. The WAG reviewed and supplemented information in these tables.

Twin Creek (AU 17010213PN 004_04)	
Description	Mainstem Twin Creek downstream of Delyle Creek
Listing Basis	Temperature: EPA Addition to 1998 303(d) list
Available Data	BURP 2001 site at top of assessment unit reach: Macro – 3; Fish - 2; Habitat – 3
	BURP 1995 site at lower end of assessment unit: Macro 1; Fish – 2; Habitat - 1
	Idaho Fish and Game Temperature Logger – temperature exceedence (year)
Land Use & Ownership	Private agricultural and livestock grazing. Forestry. Conservation easement and wetlands preservation on lower portion of Twin Creek.
Pollutant Sources	Channel modification (note restoration project to re-meander Twin Creek completed in 2001 with on-going plantings and maintenance); agriculture/livestock grazing; roads; timber harvest activities; bedload movement deposit in 1997
Recommended Action	Temperature TMDL

Dry and Delyle Creek (AU 17010213PN004_02)	
Description	Dry Creek, Delyle Creek and upper Twin Creek and its tributaries upstream of Delyle Creek
Listing Basis	Temperature: EPA Addition to 1998 303(d) list
Available Data	2002 site on mainstem Dry Creek was dry when visited.
	2001 site at top of lower assessment unit reach (Twin Creek): Macro – 3; Fish -2; Habitat – 3
	No temperature data are available.
Land Use & Ownership	Primarily Forestry and Forest Service ownership; lower reaches private, rural residential
Pollutant Sources	Roads, bedload
Recommended Action	Remove Dry Creek from the Assessment Unit. WAG members and BURP data report that it is dry except during spring run-off. TMDLs are not written for intermittent streams.
	Include upper Twin Creek and Delyle Creek in the Temperature TMDL for Twin Creek.

Unassessed Assessment Units	
Assessment Unit	**Description**
17010213PN001_02	Derr Creek
17010213PN001_03	Johnson Creek – third order portion in the delta area of the Lower Clark Fork River
17010213PN008_02	Idaho portion of Gold Creek, tributary to the Clark Fork River
17010213PN007_02	Idaho portions of West Fork Blue Creek
17010213PN006_02	Idaho portions of West Fork Elk Creek

Johnson Creek AU 17010213PN 002_02 (upper) and AU17010213PN 002_03 (lower)	
Description	West Fork Johnson Creek, tributaries and mainstem Johnson Creek to the delta
Pollutant & Listing Basis	*Sediment:* Source to mouth of Johnson Creek listed in 1994 and 1998 for sediment.
	Temperature: 1998 EPA addition for temperature.
	Flow and habitat alteration: 1994 and 1998 list
Available Data	1995 BURP site on lower reach • Below Threshold Marco score (0) • Good Fish Score (3) • Mid-range habitat (2)
	2001 BURP on lower reach • 2 macro, 2 fish, 3 habitat
	1995 BURP site on upper reach • 0 macro, n/a fish, 2 habitat • Same site in 2002 dry when visited,
	DEQ Temperature logger information shows exceedences of Salmonid Spawning Criteria
Land Use & Ownership	Forest Service, private timber on lower end. Forestry on the majority of land in watershed.
Pollutant Sources	Roads (and road failure), massive bedload movement, timber harvest
Recommended Action	Temperature TMDL Sediment TMDL

Cascade Creek (AU 17010213PN012_02)	
Description	Mainstem of Cascade Creek to Lightning Creek, including first and second order portions
Listing Basis	Temperature: EPA Addition to 1998 303(d) list
Available Data	2002 BURP site about 820 ft (250 m) upstream from Road 419 crossing – Low Macroinvertebrate Score (1) – Low Fish Score (1) – Mid-range Habitat Score (2)
Land Use & Ownership	Forest Service (Headwaters), Private forest. Forestry practiced on 92% of acreage in watershed (CWE), small acreage ranches, noxious weed issues, some rural residential
Pollutant Sources	Roads, timber harvest, bank erosion
Recommended Action	Temperature TMDL
	Sediment TMDL due to 2002 BURP data indicating not full support of beneficial uses (See Appendix X)

Upper Lightning Creek AU 17010213PN 19_02, 17010213PN 19_03	
Description	19_02: Lightning Creek and first and second order tributaries from headwaters to Rattle Creek.
	19_03: Third order portion of Johnson Creek to Clark Fork Delta
Listing Basis	Sediment: carry over from 1996 list Unknown: 2002 addition due to field studies and observation of extreme bank destabilization and bedload movement, replaced 1996 sediment listing. Current SBA indicates that sediment is impairing Lightning Creek, replace unknown with sediment.
	Flow and Habitat alteration: carry over from 1996
	Temperature: EPA Addition to 1998 303(d) list
Available Data	1999 BURP Site: Highest in watershed. Located on Lightning Creek just above Gem Creek – Full Support • Macro – 1; Fish – 2; Habitat – 3
	CWE
	Fish: bull trout below Char Falls (natural barrier). Declining trends based on Fish and Game and other agency surveys
	1998 BURP Site: • Macro – 2; Habitat – 3; no fish data
	Lightning Creek Watershed Assessment: extensive land management history, road survey and summary of landslide data. Above Rattle and below Darling lake considered relatively unimpacted, representative of historic conditions.
Land Use & Ownership	Forest Service. General Forest Management designation
Pollutant Sources	Sediment: Impacts generally below the mouth of Gem Creek. Forest roads, mass wasting, streambank erosion
	Temperature: Canopy removal (fire and historic timber harvest – 10-30 years ago)
Recommended Action	Temperature TMDL
	Sediment TMDL: One TMDL for all Lightning Creek Assessment Units, replaces “unknown”

Middle Lightning Creek AU 17010213PN 17_02, 17010213PN 17_03, 16_02, 16_03	
Description	Mainstem Lightning Creek and all tributaries between Rattle Creek and East Fork Lightning Creek, including Porcupine Creek
Listing Basis	Temperature: EPA Addition to 1998 303(d) list
	Habitat alteration: carry over from 1996
	Temperature: 1998 EPA addition
	Sediment: 1994 addition, 1998 sediment removed (replaced with unknown biological impairment). Recommend re-listing as sediment due to field studies and observation of extreme bank destabilization and bedload movement.

Available Data	Porcupine Creek BURP sites
	– 1995 (15 m upstream of confluence with Lightning Creek):
	    – Macro (3); no fish; Habitat (2)
	– 2002 (.5 miles up Porcupine Creek Road)
	    – Macro (2); fish (3); habitat (3)

	Mainstem BURP Sites
	– 1994 (just below Wellington Creek)
	    – Macro (3); no fish; Habitat (1)
	– 2002 (below Wellington and above mink creek)
	    – Macro (3); fish (1); habitat (2)

	Lightning Creek Watershed Assessment: extensive land management history, road survey and summary of landslide data.
	Fish and Game redd counts and fish population trend information – declining until recently, now holding steady at decreased number (citation)
Land Use & Ownership	Forest Service
Pollutant Sources	Sediment: Forest roads, mass wasting, streambank erosion
	Temperature: Canopy removal (fire and historic timber harvest – 10-30 years ago)
Recommended Action	Temperature TMDL
	Sediment TMDL: One TMDL for all Lightning Creek Assessment Units

Lower Lightning Creek AU 17010213PN13_02, 17010213PN13_04 , 17010213PN11_02, 17010213PN11_04, 17010213PN10_04	
Description	Fourth order mainstem and first and second order tributaries from East Fork Creek to confluence with Lower Clark Fork River
Listing Basis	Sediment: 1994 addition, 1998 sediment removed (replaced with unknown biological impairment). Unknown: 2002 addition due to field studies and observation of extreme bank destabilization and bedload movement. Impairment determined to be sediment
	Temperature: 1998 EPA addition
	Flow and Habitat alteration: carry over from 1996
Available Data	Lightning Creek Watershed Assessment: extensive land management history, road survey and summary of landslide data. Above Rattle and below Darling lake considered relatively unimpacted, representative of historic conditions.
Land Use & Ownership	Forest Service and private, forestry and some rural residential
Pollutant Sources	Sediment: Forest roads, mass wasting, streambank erosion
	Temperature: Canopy removal (fire and historic timber harvest – 10-30 years ago)
Recommended Action	Temperature TMDL
	Sediment TMDL: One TMDL for all Lightning Creek Assessment Units

Clark Fork River Mainstem Below Cabinet Gorge (AU 17010213PN03_08, PN001_08)	
Description	Mainstem Clark Fork River from Cabinet Gorge Dam to Lake Pend Oreille
Listing Basis	*TDG:* Added in 1998 for exceedences of water quality standard
	Metals/Toxics: The entire Clark Fork River was added to the 1994 303(d) list and carried over to the 1996 list for metals pollution based on public comment. The listing is retained on the 1998 and 2002 list because of exceedences of Copper, Cadmium and Zinc in the analysis period of 1998-2003.
	Temperature: 2002 addition to the 303(d) list due to measured exceedences of Idaho temperature standards.
	Flow and Habitat alteration: carryover from 1998 list
Available Data	Federal Energy Regulatory Commission license application and settlement record regarding the Avista Clark Fork Hydropower projects includes extensive baseline monitoring data on fisheries and water quality in the Lower Clakr Fork River. Data from this process show both the TDG and temperature exceedences
	USGS gaging stations below Cabinet Gorge dam – Continuous flow measurements – Nutrient and metals monitoring
	Tri-State Water Quality Council monthly data – 1984-1996: nutrient levels – 1998- present: metals and nutrient samples below Cabinet Gorge dam
Land Use & Ownership	Private, agriculture/livestock grazing, recreational areas, rural residential, hydropower operation
Pollutant Sources	Two point source permits on the river: Cabinet Gorge dam and Cabinet Gorge hatchery (both have NPDES permits for nutrients and TSS). Permits are not for TMDL pollutants.
	Metals: There are no known sources of metals pollution in Idaho. Metals contamination is attributed to transport from several possible sources in Montana, including four superfund sites upstream and possible accumulation in sediments.
Recommended Action	*Metals*: TMDL development for Cadmium, Copper, and Zinc for above and below Cabinet Gorge Assessment Units together. Continue lead monitoring to ensure adequate data record.
	Temperature: Review conditions to determine if TMDL or natural conditions provision is most appropriate.
	TDG: Develop TMDL for below Cabinet Gorge dam that incorporates the 401 certification provisions for the Cabinet Gorge Hydropower Project.

Clark Fork River Mainstem Above Cabinet Gorge (AU 17010213PN005_08)	
Description	Mainstem Clark Fork River from the Idaho/Montana border to the Cabinet Gorge Dam
Listing Basis	*Metals/Toxics:* The entire Clark Fork River was added to the 1994 303(d) list and carried over to the 1996 list for metals pollution based on public comment. The listing is retained on the 1998 and 2002 list because of exceedences of Copper, Cadmium and Zinc during the past ten years.
	TDG: Added in 1998 for exceedences of water quality standard.
	Temperature: 2002 addition to the 303(d) list due to measured exceedences of Idaho temperature standards.
	Flow and Habitat alteration: carryover from 1998 list.
Available Data	Federal Energy Regulatory Commission license application and settlement record regarding the Avista Clark Fork Hydropower projects includes extensive baseline monitoring data on fisheries and water quality in the Lower Clark Fork River. Data from this process show both the TDG and temperature exceedences
	Tri-State Water Quality Council monthly and peak flow data – 1984-1996: nutrient levels – 1998- present: metals and nutrient samples in Cabinet Gorge reservoir near Noxon Bridge, Montana
Land Use & Ownership	Private, agriculture/livestock grazing, recreational areas, rural residential, hydropower operation
Pollutant Sources	*Metals*: There are no known sources of metals pollution in Idaho. Metals contamination is attributed to transport from several possible sources in Montana, including four superfund sites upstream and possible accumulation in sediments.
	Temperature: Altered flow regime and reservoirs upstream, and possible canopy removal.
Recommended Action	*Temperature*: Review conditions and coordinate with the State of Montana to determine if TMDL or natural conditions provision is most appropriate.
	Metals: TMDL development for Cadmium, Copper, and Zinc for above and below Cabinet Gorge Assessment Units together. Continue lead monitoring to ensure adequate data record.
	TDG: Develop TMDL for above Cabinet Gorge Assessment Unit.

Wellington Creek AU 17010213PN20_02	
Description	First and second order portions of Wellington Creek from the headwaters to Lightning Creek
Listing Basis	Temperature: 1998 Temperature addition by EPA (Headwaters to mouth)
	Sediment: 1994, 1998 listing carryover (Falls to Lightning Creek), 2002 entire AU
Available Data	1998 Temperature logger information near mouth exceeds aquatic life standards
	Lightning Creek Watershed assessment indicates extensive roading and landslide (natural and road-related) in the watershed. PBTTAT (1998) indicates populations are limited or threatened by excess bedload, loss of large woody debris in the system, and altered water flows as a result of unstable channels.
	– BURP 1996 (above falls) 25-30 m upstream road 1016 bridge and above the falls • Macro – 1; no fish; Habitat -3 – BURP 1995 (above falls): 25-30 m upstream road 1016 bridge and above the falls • Macro - 3; No Fish Score; Habitat Score – 1
	– 1997: Location below Wellington Creek Falls – Macro – 3 (just barely above 2); Habitat – 3
	Fish and Game and joint agency surveys – Bull trout, westslope cutthroat and rainbow trout below falls. – Declining bull trout redd densities from 1983-1998. – Bull trout densities declining between 1984 (snorkel survey) and 1997 (electrofishing)
Land Use & Ownership	Forest Service
Pollutant Sources	Lightning Creek assessment ranks current road conditions as relatively low risk, with a few exceptions. While there is landsliding, Cacek (1989) found that few reached the channel.
	Four large mass failures that contribute to channel. (CWE)
	Historic clearcuts in South Fork and mainstem Wellington Creek. More recent (1988) helicopter logging on north aspect of mainstem. Little harvest in high landslide risk areas.
Recommended Action	Temperature TMDL
	Sediment: Wellington Creek specific TMDL

East Fork Creek AU 17010213PN014_02, 17010213PN014_03	
Description	Portions including mainstem East Fork Creek from Idaho/Montana border to Savage Creek and from Savage Creek to Lightning Creek, also including first and second order portions of East Fork Creek.
Listing Basis	*Temperature:* 1997 DEQ temperature data shows violations of temperature standards during critical times.
	Sediment: 1994 BURP data, 1998 303 (d) list
Available Data	1994 Site; Located below confluence with Savage Creek – Macro 1; Fish 3; Habitat 1
	1995 Site; Located above confluence with Savage Creek • Macro 3; Fish 0, Habitat 1
	2002 Site; Located below the Savage Creek confluence with East Fork Creek – Not Full Support – Macro 1; Fish 3; Habitat 3
	2002 Site; Located above confluence with Savage Creek – Not Full Support – Macro 1; Fish 3; Habitat 3
	CWE 2003
Land Use & Ownership	Forest Service
Pollutant Sources	Sediment: Impacts generally from forest roads, mass wasting, streambank erosion
	Temperature: Canopy removal
Recommended Action	Temperature TMDL
	Sediment: Based on preliminary model, East Fork Creek does not require a watershed level TMDL, however, load reductions on East Fork Creek will contribute to meeting the TMDL for the mainstem Lightning Creek [pending target discussion]

Savage Creek AU 17010213PN015_02	
Description	First and second order portions of Savage Creek from Idaho/Montana border to East Fork Creek.
Listing Basis	Temperature: 1998 DEQ temperature data shows violations of temperature standards during critical times.
Available Data	1999 Site: BURP site located 100 meters upstream from confluence with East Fork Creek. – Macro 1; Fish NA; Habitat 3 – Full Support
	1998 DEQ temperature data
	2004 Lightning Creek Watershed Assessment • Bedload deposition concerns • Above historic logging areas and roads, considered one of the least disturbed areas in Lightning Creek drainage • Extensive road condition surveys and sediment delivery information available
	PBTAT – considers area highly unstable and in poor condition. Adfluvial bull trout use 2.3 km of channel for spawning.
Land Use & Ownership	Forest Service
Pollutant Sources	Temperature: Canopy removal (lower Savage historic timber, fire activity)
Recommended Action	Temperature TMDL

Rattle Creek 17010213PN018_02	
Description	First and second order portions of Rattle Creek from headwaters to Lightning Creek.
Listing Basis	Temperature: Failing temperature standards during critical times
Available Data	1995 Site: BURP site located approximately 0.5 miles upstream from confluence with Lightning Creek. – Macro 1 Fish NA; Habitat; 1
	2002 Site: BURP site located approximately 0.5 miles upstream from confluence with Lightning Creek. – Macro 1; Fish 3; Habitat 3
	CWE 2003
Land Use & Ownership	Forest Service
Pollutant Sources	Temperature: Canopy removal
	Sediment: high road density in the basin, road failure, mass wasting and past timber harvest activities
Recommended Action	Temperature TMDL
	Sediment TMDL: separate Rattle Creek TDML and a part of overall Lightning Creek TMDL???

Spring Creek 17010213PN021_02	
Description	Spring Creek from headwaters to Lightning Creek, plus Cougar Creek
Listing Basis	Not listed
Available Data	1995 BURP data show Full Support. Subsequent revision of the macroinvertebrate index indicates that this data would now be characterized as not fully supporting beneficial uses.
	Current status determination needs verification due to the age of data, and the refinement of the support indices since data were collected at Spring Creek. Recent DEQ site visits indicate that there are potential water quality concerns in the watershed.
	CWE data indicate that water quality and beneficial uses are being maintained in the forestry portions of the watershed where Site Specific Best Management Practices are followed.
Land Use & Ownership	Forest Service, private timberland and rural residential
Pollutant Sources	Potential sedimentation and flow alteration from proposed hydropower project and active rural development
	Forest roads and stream crossings
	Point Source pollution permit for Spring Creek (Clark Fork) Fish and Game hatchery, however, the hatchery is not currently in operation. Therefore, there are not pollution contributions at this time.
Recommended Action	Temperature: Advisory TMDL. Potential Natural vegetation model shows load reduction needed.
	Reassessment of the watershed status due to dated BURP data and recent development activities that may be impacting the water quality status of the Creek.
	Recommend separating out Cougar Creek as a separate assessment unit because there is different land use/ownership patterns and it flows into Denton Slough, while Spring Creek flows into Lower Lightning Creek. Assessment of Cougar Creek is also recommended as no information is currently available regarding the status of Cougar Creek.

Mosquito Creek	
Description	Mosquito Creek headwaters to confluence with Lower Clark Fork River
Listing Basis	Full Support
Available Data	1995 Site Lower Mosquito Creek – Macro (1); no fish; Habitat (1); Average (1)
	2002 Site Lower Mosquito Creek, just upstream from 1995 site – Macro (3); Fish (1); Habitat (2); Average (2). Delisted in 2000 based on this data
Land Use & Ownership	Mostly private forestry and rural residential
Pollutant Sources	Potential forest road or development related impacts.
Recommended Action	Advisory TMDL for temperature. Potential Natural Vegetation Model shows some load reduction needed.

Status of Beneficial Uses

Each major tributary in the subbasin was visited at least once by BURP crews between 1995-2002. Figure X shows the locations of BURP monitoring sites, and Table X documents index scores for each site, results of which are discussed above. Of the 33 records, 16 sites were not assessed due to lack of data, while the other 19 sites were evaluated for their support of their beneficial uses based upon reference condition indices. In addition, temperature data were collected by DEQ and other entities and show exceedences in every waterbody measured. Eight watersheds in the subbasin have been listed for temperature impairment in the 2002 Integrated Report (IDEQ 2005). Johnson Creek BURP data indicated not fully support for cold water aquatic life and salmonid spawning and it is listed as impaired by sediment and temperature. While BURP scores indicated full support, there is a margin of error inherent in the indices and extensive field information from the Forest Service and the Lightning Creek Watershed Assessment indicate that the unknown biological impairment in the Lightning Creek drainage can most logically be attributed to sediment pollution, and therefore, sediment TMDLs will be developed for the Lightning Creek drainage.

The unassessed sites were spread throughout the subbasin and generally were not assessed due the site being dry when the BURP crew visited the site. BURP data from Spring Creek were collected when DEQ used a different macroinvertebrate index, and reassessment is recommended.

Conclusions

Existing data indicate continued impairment on the Lower Clark Fork River mainstem by temperature and total dissolved gas, as well as flow and habitat alteration. TMDLs will address both temperature and TDG. Metals TMDLs will be developed for the three Lower Clark Fork Assessment Units, and on-going monitoring should continue. It is believed that the reservoirs act as metal and nutrient sinks, and the water quality in the mainstem below Cabinet Gorge dam is generally better than further upstream, however future monitoring and a TMDL are necessary.

Temperature exceedences occur throughout the watershed. Critical times for exceedence follow seasonal temperature and native fish requirements. East Fork Creek and Johnson Creek were found to need further monitoring and a TMDL is developed to address the level of sediment pollutants which are known. Cascade Creek is listed for temperature impairment, however the BURP data indicate there may be other biological impairments. It is recommended that further information be collected on Cascade Creek to determine if other pollutants are causing impairments.

The instability of stream structure in Lightning Creek and its tributaries, and their ability to support healthy bull trout populations is a critical indicator of impairment and subsequent restoration that will be targeted in the TMDLs. Middle Lightning Creek, as the major depositional reach in the drainage, indicates the level of aggradation and stream channel alteration due to excess sediment. Currently, the Lightning Creek system currently does not have the capacity to assimilate the amount of bedload material moved through the system, resulting in a widening channel structure and water going underground in the lower reaches, sometimes creating fish passage barriers during critical fall spawning periods.

2.5 Data Gaps

The beneficial use status of Spring Creek needs verification. Due to a change in BURP indexing, it is unknown whether the previous support status determination is still valid. Additional BURP monitoring of Spring Creek to reassess its support status is needed. In addition to the non-operation status of the Clark Fork hatchery which is expected to improve water quality, there are changed land use activities that may be impacting water quality on this stretch of water as well.

Exceedence of Water Quality Standards for metals has decreased since the Lower Clark Fork River was first listed for metals in 1994. This can be attributed to on-going remediation efforts upstream in Montana. Continued metals monitoring is necessary in the Lower Clark Fork River to monitor progress toward the TMDL target and to monitor potential excursions from the standards due to the proposed Rock Creek mine directly upstream of the border, and remediation efforts at the Milltown dam site.

As TDG mitigation projects progress, continued assessment to ensure desired conditions are reached is necessary.

3. Subbasin Assessment–Pollutant Source Inventory

This section discusses known sources of sediment, temperature and metals – the pollutants of concern in this subbasin. Information on point and non-point sources is summarized and data gaps are identified for future research and monitoring.

3.1 Sources of Pollutants of Concern

While there are two point sources permitted to discharge pollutants into the Lower Clark Fork River, nonpoint sources of pollution are the major contributor to impairment in this Subbasin. Generally, pollution within the Lower Clark Fork Subbasin is related to land use and is primarily from excess sediment and high temperatures as a result of historic timber harvest, fires and associated road building on the highly unstable soils of the region.

Point Sources

There are two active point source permits in the Subbasin, and one inactive permit. In addition, there is a general permit for construction that is applicable to areas greater than one acre in the Subbasin. Table X summarizes discharge limits and permit information for each location. While there are no other point sources on the Idaho portion of the Subbasin, it should be noted that upstream in Montana, there is a large Superfund site encompassing much of the Lower Clark Fork River basin and extensive metals clean-up efforts are underway.

Nonpoint Sources

Sediment

Sediment occurs naturally as a geologic process. Streams function to move sediment from source areas of high gradient and friable soil material through intermediate elevations and gradients to depositional reaches where sediment is incorporated into the flood plain or transported to larger waters and ultimately to the ocean. Land management practices have the potential to accelerate erosion or to alter depositional processes. This is when sediment becomes pollution. Sediment in excess of a stream's ability to transport it is pollution. Sediment pollution interferes with natural processes that aquatic life depends on and it can result in increased instability of natural stream channels further accelerating erosion. Both fine sediment, and excessive bedload (or larger sediment) can be a pollutant.

Land conditions that result from silvicultural practices and roads in the area are the primary non-point sources of sedimentation. Timber harvest and associated road construction can intercept water flows and alter peak flows, as well as provide trigger points for mass wasting events. These altered flows and sediment delivery mechanisms influence stream function. Altering the dimension, pattern and profile of stream channels changes the transport and deposition of sediment as well as morphology of streams and rivers. For instance, the widening of a channel can contribute to higher temperatures in the stream. To address one aspect of sediment pollution without regard to others on a watershed scale has little potential to successfully reduce sediment or improve water quality or fisheries on a meaningful scale.

Initiating an increase in erosion or change in flow pattern can have grave consequences over many years. Many of the processes that are creating excessive amounts of sediment were initiated before these relationships were understood. Today, a number of land management practices are perpetuating the problems of the past and contributing to an increasing deficit of water quality and fisheries values.

Road densities in the area are reported in Table X. Stream crossings provide added sources of sediment and channel alteration. Maps created by PWA (2004) that show stream crossing and mass failures in the Lightning Creek drainage are reproduced in Appendix X.

Mass wasting is a natural process in the Lower Clark Fork Subbasin, in particular in the Lightning Creek watershed. An illustrative example of the impacts of logged and roaded versus unlogged terrain in the Subbasin is given in the Lightning Creek Watershed Assessment (PWA 2004). Morris Creek is a relatively undisturbed watershed, and has had several mass wasting events occur that are not linked to human activities. The structure in Morris Creek is considered more stable than its counterpart – East Fork Creek, which has had substantially more road related mass wasting events.

Temperature

The primary disturbance causing stream temperatures to rise is reduced canopy cover and riparian function by silvicultural and in the lower stretches of some of the southern tributaries, agricultural practices.

Roads located close to the streams limit stream shaping in some areas, and the widening of the channel due to changes in sediment delivery can impact the amount of temperature loading that occurs in the stream.

Metals

There are no known sources of metals in Lower Clark Fork subbasin in Idaho. A century of mining and smelting, tailings disposal, and other mine wastes have left the Upper Clark Fork and its tributaries severely polluted with toxic metals and other chemicals. Four Superfund sites exist in the upper Clark Fork: 1) Silver Bow Creek and the upper Clark Fork from Butte to Milltown (metals residues from mining and smelting); 2) the Montana Pole plant in Butte (creosote and pentachlorophenol from wood treatment); 3) the Anaconda smelter (smelter wastes and widespread deposition of airborne contaminants; and 4) the Milltown Reservoir, which has accumulated toxic metals from upstream sources. Since 1982, EPA, Montana DEQ, industries and other agencies have worked to investigate, prescribe and implement clean-up procedures. Most notably, in 2006, removal of contaminated sediment from the Milltown reservoir will begin, followed by removal of the dam and a long-term remediation and monitoring program (EPA 2005).

Pollutant Transport

Sediment

Delivery of large material thru the system is episodic during the winter and spring months when high flows and/or rain on snow events occur. The road system frequently encroaches on the riparian areas resulting in some chronic delivery. Due to the soil characteristics of the subbasin, road intercept water and increase the potential for mass wasting. In a 1998 study of landslides in the Lightning Creek drainage, Cacek found that 7% of landslides originated from roads or roads and clearcuts. Anthropogenic increases in mass wasting are very evident in the Lightning Creek drainage and are a significant source of sediment pollution through both stream alteration and direct delivery to the stream.

Temperature

Temperature exceedences are exclusively from non-point sources. Some increases in temperature can be attributed to canopy cover. Alterations in stream structure, in particular, stream widening due to excessive erosion or large sediment delivery can also influence temperatures. Therefore, it is possible for temperature pollution to be related to sediment transport and deposition areas.

Metals

Sources of metals to the Clark Fork River are entirely upstream of the Cabinet Gorge and Noxon Rapids dams. Most metals settles and bind to sediment particles, generally accumulating in the reservoirs along the Clark Fork River, including Noxon Reservoir and Cabinet Gorge to a lesser extent. A catastrophic flood event may remobilize these bottom sediments and affect beneficial uses in downstream waters, however, at this point it is highly speculative without further study. Studies of stratification in Noxon reservoir have been conducted to determine if anoxic conditions are occurring, and this condition has not be recorded to date (citation). Future monitoring will occur during extreme low flow years when these conditions could occur.

3.2 Data Gaps

On-going activities to improve bull trout habitat are likely to have a positive impact on water quality as well. It will be important to monitor the impact of these activities, in particular sediment input reductions.

Point Sources

There are only two point sources of pollution, both on the Lower Clark Fork River. Because of the Lower Clark Fork River's influence on Lake Pend Oreille, it is important to continue monitoring for nutrient input from these sources. (Lake Pend Oreille nearshore areas have a TMDL and implementation plan in place for reducing nutrient inputs into the lake.)

Since both the Lower Clark Fork River and Lightning Creek are designated Special Resource Waters, no new point sources of pollution are anticipated.

Nonpoint Sources

Water quality information is unavailable for some of the smaller tributaries in the area and should be collected. Given the number of temperature exceedences and on-going data collection, more analysis of background temperature conditions in the watershed may be warranted.

4. Subbasin Assessment – Summary of Past and Present Pollution Control Efforts

There are active bull trout restoration efforts in many parts of the Subbasin. In particular, since the Clark Fork Settlement Agreement, there have been staff and funds dedicated to restoration by Avista Utilities and prioritization of efforts by the Clark Fork Technical Advisory Committee.

Point Source Pollution Permits

There are two permitted point sources of pollution in the Lower Clark Fork Subbasin – the Cabinet Gorge Fish Hatchery and the Cabinet Gorge Power station. In addition, if a construction project disturbs more than one acre of land (or is part of a larger common development that will disturb more than one acre), the operator is required to apply of a pollution permit from EPA after developing a site-specific Storm Water Pollution Prevention Plan. A Construction General Permit has been issued by EPA, so that construction operators in Idaho that meet specific requirements to control sediment and other best management practices, document these measures in their Storm Water Pollution Prevention Plan and monitor their implementation for the life of project, will receive coverage in this permit.

Cabinet Gorge Hatchery (Permit number ID-002661-1) has a permit that limits effluent as outlined in Table X.

Idaho Fish and Game's Clark Fork Hatchery was covered under the Aquaculture Facilities in Idaho General NPDES Permit No. ID-G-13-0021 until the permit expired in September 2004, when the permit was placed on administrative hold due to a temporary shutdown of the hatchery that went into effect in August 2000. Effluent Inputs from the hatchery went directly into Spring Creek. Since the hatchery is not in operation, some water quality improvements can be expected. If/when the hatchery begins operation again, a revised permit would account for the information presented in this TMDL.

Non-Point Source

Forested Land/Roads

Due to the importance of the Lower Clark Fork, and the Lightning Creek watershed in particular, to bull trout, extensive efforts are underway to improve water quality and restore habitat in the Lower Clark Fork drainage. In the past ten years, significant data collection and planning for restoration have occurred, and several projects are underway or have been completed over the past five years with many more in the works. Restoration projects in the Lightning Creek watershed focus primarily on reducing the impacts of the road system on the streams in the watershed. This includes decommissioning roads and culvert repair, as well as improved maintenance. Over time, efforts such as these will reduce sediment pollution both directly from roads and as a reduction in road related mass wasting. Reductions in sediment pollution will also increase the potential of reaching shade targets and cooling efforts because of the relationship of excessive sediment to stream widening.

Agricultural

On agricultural lands under federal management, the attention is being given to road impacts. In addition, a stream realignment project on Twin Creek was completed in 1999. The project was a partnership between the landowner, Idaho Fish and Game and the Technical Committee in the Avista Settlement agreement. *This project…*

Bull Trout Restoration Projects

As a result of the Clark Fork Settlement Agreement, there have been numerous projects completed to benefit bull trout populations, many of which are directly related to improving water quality in the Subbasin. The projects fall into several general categories. Land parcels in prime bull trout habitat have been acquired in Idaho and Montana. Placement of lands in conservation easements or ownership reduces pressures from development in these areas and protects critical riparian areas. A native salmonid restoration strategy is in place, which includes genetic studies, telemetry and development of methods to pass fish upstream and downstream of the dams. Extensive monitoring of tributary and mainstem fish population abundance and habitat use is ongoing. Several watershed councils and state fish and game agencies are supporting for on-the-ground restoration and education projects.

Nutrient Reduction Projects

The States of Idaho and Montana, facilitated by the Tri-State Water Quality Council, have a Memorandum of Understanding that documents the parties' commitments and intent to protect and maintain water quality in Pend Oreille Lake by establishing and attaining nutrient loading goals and targets for the Clark Fork watershed in Montana and local sources in Idaho. Specific loading targets are set to reduce the amount of nitrogen and phosphorus in the Clark Fork Pend Oreille system.

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5. Total Maximum Daily Load(s)

A TMDL prescribes an upper limit on discharge of a pollutant from all sources so as to assure water quality standards are met. It further allocates this load capacity (LC) among the various sources of the pollutant. Pollutant sources fall into two broad classes: point sources, each of which receives a wasteload allocation (WLA); and nonpoint sources, each of which receives a load allocation (LA). Natural background (NB), when present, is considered part of the LA, but is often broken out on its own because it represents a part of the load not subject to control. Because of uncertainties regarding quantification of loads and the relation of specific loads to attainment of water quality standards, the rules regarding TMDLs (Water quality planning and management, 40 CFR Part 130) require a margin of safety (MOS) be a part of the TMDL.

Practically, the margin of safety is a reduction in the load capacity that is available for allocation to pollutant sources. The natural background load is also effectively a reduction in the load capacity available for allocation to human-made pollutant sources. This can be summarized symbolically as the equation: LC = MOS + NB + LA + WLA = TMDL. The equation is written in this order because it represents the logical order in which a loading analysis is conducted. First the load capacity is determined. Then the load capacity is broken down into its components: the necessary margin of safety is determined and subtracted; then natural background, if relevant, is quantified and subtracted; and then the remainder is allocated among pollutant sources. When the breakdown and allocation are completed the result is a TMDL, which must equal the load capacity.

Another step in a loading analysis is the quantification of current pollutant loads by source. This allows the specification of load reductions as percentages from current conditions and considers equities in load reduction responsibility. The load capacity must be based on critical conditions – the conditions when water quality standards are most likely to be violated. If protective under critical conditions, a TMDL will be more than protective under other conditions. Because both load capacity and pollutant source loads vary, and not necessarily in concert, determination of critical conditions can be more complicated than it may appear on the surface.

A load is fundamentally a quantity of a pollutant discharged over some period of time, and is the product of concentration and flow. Due to the diverse nature of various pollutants, and the difficulty of strictly dealing with loads, the federal rules allow for "other appropriate measures" to be used when necessary. These "other measures" must still be quantifiable, and relate to water quality standards, but they allow flexibility to deal with pollutant loading in more practical and tangible ways. The rules also recognize the particular difficulty of quantifying nonpoint loads and allow "gross allotment" as a load allocation where available data or appropriate predictive techniques limit more accurate estimates. For certain pollutants whose effects are long term, such as sediment and nutrients, EPA allows for seasonal or annual loads.

5.1a In-stream Water Quality Targets Metals

Water quality targets for temperature, metals and sediment are detailed in the following section for waterbodies currently not fully supporting beneficial uses. The goal of the targets is to restore "full support of designated beneficial uses" (Idaho Code 39.3611, 3615). Select the measurable target(s) for in-stream water quality and the loading analysis.

Metals TMDL

Because of exceedences of the cadmium, zinc and copper standards as detailed in Section 4 (on page X of this document), metals TMDLs are presented below for the Lower Clark Fork River. These TMDLs apply to all three Assessment Units and the point of compliance is the USGS gaging station at Cabinet Gorge.

Design Conditions

While high flows tend to show the most sediment transport, and therefore have the greatest potential to transport metals, lower flows may show exceedences more readily due to the lower threshold of metals that can be absorbed into the system. All seasons are considered in the following analysis. High flows generally relate to lower hardness levels; therefore targets have been developed based on the lowest measured hardness values at the USGS Cabinet Gorge gaging station.

Target Selection

Water Quality Standards include numeric standards for metals, dependent on the hardness value. Because hardness varies with flows and measures are not always available, a conservative approach to developing targets is undertaken. The minimum hardness level measured from all records at the USGS gaging station below Cabinet Gorge dam is 64 mg/l, based on measured Calcium and Magnesium values.

Monitoring Points

Idaho DEQ will continue to participate as a member of the Tri-State Water Quality Council monitoring committee to coordinate monitoring efforts in the Lower Clark Fork River. Noxon Bridge will be used to track compliance with the TMDL. Metals and nutrients are monitored monthly and six times during peak flows. Monitoring protocols are reported in the Quality Assurance Protection Plan for the Tri-State Water Quality Council Program (PBS &J, 2005).

5.2a Load Capacity Metals

The load capacity is the amount of pollutant that each water body can accommodate and still meet the water quality standard. This must be a level to meet "...water quality standards with season variations and a margin of safety which takes into account any lack of knowledge..." (Clean Water Act § 303(d)(C)). Since flows can vary significantly in the watershed, load capacity has been determined based on flow. In addition to the margin of safety allowed by using the lowest hardness value to calculate the standard, a 10% margin of safety is applied to load capacity.

Table X. Load Capacity of the Lower Clark Fork River for Copper.

Copper Load Capacity					
	Flow (cfs)	Copper CCC (ug/L)	Load Capacity (lb/day)	MOS (lbs/day)	Load Capacity - MOS (lbs/day)
7Q10	6054	7.8	254	25	229.
10th percentile*	8400	7.8	353	35	318
50th percentile*	16900	7.8	710	71	639
90th percentile*	44600	7.8	1875	187	1688

Table X. Load Capacity of the Lower Clark Fork River for Zinc.

Zinc Load Capacity					
	Flow (cfs)	Zinc CCC (ug/L)	Load Capacity (lb/day)	MOS (lbs/day)	Load Capacity - MOS (lbs/day)
7Q10	6054	80	2610	261	2349
10th percentile*	8400	80	3621	362	3259
50th percentile*	16900	80	7286	729	6557
90th percentile*	44600	80	19228	1923	17305

Table X. Load Capacity of the Lower Clark Fork River for Cadmium.

Cadmium Load Capacity					
	Flow (cfs)	Cadmium CCC (ug/L)	Load Capacity (lb/day)	MOS (lbs/day)	Load Capacity - MOS (lbs/day)
7Q10	6054	0.74	24	2.4	21.6
10th percentile*	8400	0.74	33	3.3	29.7
50th percentile*	16900	0.74	67	6.7	60.3
90th percentile*	44600	0.74	178	17.8	160.2

* Based on 1960-2004 USGS dataset.

5.3a Estimates of Existing Pollutant Loads Metals

Regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(I)). There are no known point sources of metals in the Lower Clark Fork River subbasin. The primary non-point sources are assumed to be historical mining sites upstream in Montana, including four superfund sites. Background loads and impacts of historic mining activity are considered together.

Copper Existing Load				

	Flow (cfs)	Copper (ug/L)	Existing Load (lbs/day)	Reduction Required (lbs/day)	% Reduction
7Q10	6054	12	391	162.47	41.50
10th percentile*	8400	12	543	225.43	41.50
50th percentile*	16900	12	1093	453.54	41.50
90th percentile*	44600	12	2884	1196.93	41.50

Zinc Existing Load					
	Flow (cfs)	Zinc (ug/L)	Existing Load (lbs/day)	Reduction Required (lbs/day)	% Reduction
7Q10	6054	80.8	2636	287.10	10.89
10th percentile*	8400	80.8	3658	398.35	10.89
50th percentile*	16900	80.8	7359	801.44	10.89
90th percentile*	44600	80.8	19420	2115.05	10.89

Cadmium Existing Load					
	Flow (cfs)	Cadmium (ug/L)	Load (lb/day)	Reduction Required (lb/day)	% Reduction
7Q10	6054	1	32.6247	10.90	33.40
10^{th} percentile*	8400	1	45.2671	15.12	33.40
50^{th} percentile*	16900	1	91.0731	30.42	33.40
90^{th} percentile*	44600	1	240.3469	80.28	33.40

Table X. Current loads from non-point sources in Lower Clark Fork River Subbasin.

Load Type	Location	Load	Estimation Method
Non-Point Source Mine wastes	Upstream of Montana Border, various locations		There are no known sources in Idaho, therefore the entire load was allocated to Montana.

5.4a Load Allocation Metals

The entire load allocation is designated at the Montana-Idaho border and it is the responsibility of the state of Montana to meet load capacity and Idaho water quality standards at the border.

Margin of Safety

The standards used were based on the minimum hardness level calculation, providing a margin of safety. A 10% margin was also applied to account for measurement error. In addition, background load for the system is not known, therefore it is assumed to be zero.

Seasonal Variation

Seasonal variation is accounted for in the assignment of target loads based upon flow levels.

Reasonable Assurance

Significant resources and legal commitments are tied to several major Superfund clean-up efforts in the Clark Fork River Basin in Montana. In addition, TMDLs and load reductions are being completed in the Upper Clark Fork River by Montana DEQ. Because the sources of metals in Idaho are believed to be the same that are causing metals impairment in Montana, the on-going remediation efforts in Montana should also help to meet Idaho Water Quality Standards. Also, Montana must bring the Clark Fork River into compliance with its own Water Quality Standards, which should assure that Idaho's standards will be met at the border.

Background

Background levels are unknown, therefore there is no allocation for background.

Reserve

No part of the wasteload allocation is held for future sources. Even when the target loads are met, the Clark Fork River is a designated as a Special Resource Water and no measurable increase in existing levels of pollutants is allowed.

Remaining Available Load

There is no available load at the Idaho border for metals. Even when the TMDL targets are met, no measurable discharge of metals is allowed into the Clark Fork River because it is a designated Special Resource Water.

Table X. Nonpoint source load allocations for Lower Clark Fork River Subbasin.

Source	Pollutant	Allocation	Time Frame for Meeting Allocations
Non-Point Mine Wastes	Cadmium, Zinc, Copper		2011

5.5a Implementation Strategies

DEQ recognizes that implementation strategies for TMDLs may need to be modified if monitoring shows that the TMDL goals are not being met or significant progress is not being made toward achieving the goals.

Time Frame and Approach

It is anticipated that the targets will be met within five years due to on-going and past efforts to reduce metals that should continue to show improvements. In the 1980s, there were frequent exceedences in metals (IDEQ, 2001), while, a noticeable decrease in metals exceedences has occurred since the early 1990s. While it is not anticipated (cite EPA Milltown documents), the removal of the Milltown dam beginning in 2006 may increase the potential for metals transport downstream. However, this is not expected to slow progress toward achievement of TMDL targets. If unexpected transport downstream occurs, additional monitoring efforts will be triggered to prevent exceedence at the border.

Responsible Parties

Because all the metals sources are outside of Montana, allocation for responsibility for reductions is left to the State of Montana DEQ.

Monitoring Strategy

Monitoring by the Tri-State Water Quality Council will continue to record levels of metals on a monthly basis and during peak flows in the mainstem Clark Fork River above and below Cabinet Gorge dam.

5.1b In-stream Water Quality Targets Temperature

For the Lower Clark Fork Subbasin temperature TMDLs we utilize a potential natural vegetation (PNV) approach. If natural conditions exceed numeric water quality criteria, exceedance of the criteria is not considered to be a violation of water quality standards (IDAPA 58.01.02.200.09). In these situations, natural conditions essentially become the water quality standard, and the natural level of shade and channel width become the target of the TMDL. The in stream temperature which results from attainment of these conditions is consistent with the water quality standards, even though it may exceed numeric temperature criteria. See Appendix B for further discussion of water quality standards and background provisions. The PNV approach is described below. Additionally, the procedures and methodologies to develop PNV target shade levels and to estimate existing shade levels are described in this section. For a more complete discussion of shade and its affects on stream water temperature, the reader is referred to the South Fork Clearwater Subbasin Assessment and TMDL (IDEQ, 2004)

<u>Potential Natural Vegetation for Temperature TMDLs</u>

There are a several important contributors of heat to a stream including ground water temperature, air temperature and direct solar radiation (Poole and Berman 2001). Of these, direct solar radiation is the source of heat that is most likely able to be controlled or manipulated. The parameters that affect or control the amount of solar radiation hitting a stream throughout its length are shade and stream morphology. Shade is provided by the surrounding vegetation and other physical features such as hillsides, canyon walls, terraces, and high banks. Stream morphology affects how closely riparian vegetation grows together and water storage in the alluvial aquifer. Streamside vegetation and channel morphology are factors influencing shade, which are most likely to have been influenced by anthropogenic activities, and which can be most readily corrected and addressed by a TMDL.

Depending on how much vertical elevation also surrounds the stream, vegetation further away from the riparian corridor can provide shade. However, riparian vegetation provides a substantial amount of shade on a stream by virtue of its proximity. We can measure the amount of shade that a reaches a stream in a number of ways. Effective shade, that shade provided by all objects that intercept the sun as it makes its way across the sky, can be measured in a given spot with a solar pathfinder or with optical equipment similar to a fish-eye lens on a camera. Effective shade can also be modeled using detailed information about riparian plants and their communities, topography, and the stream's aspect. In addition to shade, canopy cover is a similar parameter that affects solar radiation. Canopy cover is the vegetation that hangs directly over the stream, and can be measured using a densiometer, or estimated visually either on site or on aerial photography. All of these methods tell us information about how much the stream is covered and how much of it is exposed to direct solar radiation.

Potential natural vegetation (PNV) along a stream is the shade produce by an intact riparian plant community that has grown to its fullest extent and has not been disturbed or reduced in anyway. The riparian vegetation can be removed by disturbance either naturally (wildfire, disease/old age, wind-blown, wildlife grazing) or anthropogenically (domestic livestock grazing, vegetation removal, logging, streambank failure due to erosion). The idea behind PNV as targets for temperature TMDLs is that PNV provides a natural 'mature state' level of solar loading to the stream. Any less shade than that provided by PNV results in an increase in water temperatures from either naturally created or anthropogenically created additional solar inputs. We can estimate PNV shade from models of plant community structure (shade curves for specific riparian plant communities), and we can measure existing vegetative cover or shade. Comparing the two will tell us how much excess solar load the stream is receiving, and what potential there is to decrease solar gain. Streams that have been disturbed by human activity may require additional restoration above and beyond natural recovery (e.g., addition of biologs or other restoration efforts that supplement natural recovery).

Existing shade or cover was estimated for all the major water bodies seen on a 1:100K hydrography from visual observations of aerial photos. These estimates were field verified by measuring shade with a solar pathfinder at systematically located points along the streams (see below for methodology). PNV targets were determined from an analysis of probable vegetation at the creeks and comparing that to shade curves developed for similar vegetation communities in other TMDLs. A shade curve shows the relationship between effective shade and stream width. As a stream gets wider, the shade decreases as the vegetation has less ability to shade the center of wide streams. As the vegetation gets taller, the more shade the plant community is able to provide at any given channel width. Existing and PNV shade was converted to solar load from data collected on flat plate collectors at the nearest National Renewable Energy Laboratory (NREL) weather stations collecting these data. In this case, an average of the Spokane, WA and Kalispell, MT stations was used. The difference between existing and potential solar load, assuming existing load is higher, is the load reduction necessary to bring the stream back into compliance with water quality standards (see Appendix B). PNV shade and loads are assumed to be the natural condition, thus stream temperatures under PNV conditions are assumed to be natural (so long as there are no point sources or any other anthropogenic sources of heat in the watershed), and are thus considered to be consistent with the Idaho water quality standards, even though they may exceed numeric criteria.

Pathfinder Methodology

The solar pathfinder is a device that allows one to trace the outline of shade producing objects on monthly solar path charts. The percentage of the sun's path covered by these objects is the effective shade on the stream at the spot that the tracing is made. In order to adequately characterize the effective shade on a reach of stream, ten traces should be taken at systematic or random intervals along the length of the stream in question.

At each sampling location the solar pathfinder should be placed in the middle of the stream about one foot above the water or at a level consistent with the bankfull water line. Follow the manufacturer's instructions (orient to true south and level) for taking traces. Systematic sampling is easiest to accomplish and still not bias the location of sampling. Start at a unique location such as 100 m from a bridge or fence line and then proceed upstream or downstream stopping to take additional traces at fixed intervals (e.g. every 100m, every half-mile, every degree change on a GPS, every 0.5 mile change on an odometer, etc.). One can also randomly locate points of measurement by generating random numbers to be used as interval distances.

It is a good idea to take notes while taking solar pathfinder traces, and to photograph the stream at several unique locations. Pay special attention to changes in riparian plant communities and what kinds of plant species (the large, dominant, shade producing ones) are present. Additionally or as a substitution, one can take densiometer readings at the same location as solar pathfinder traces. This provides the potential to develop relationships between canopy cover and effective shade for a given stream.

Aerial Photo Interpretation

Canopy coverage estimates or expectations of 'shade' based on plant type and density are provided for natural breaks in vegetation density, marked out on a 1:100K hydrography. Each interval is assigned a single value representing the bottom of a10% canopy coverage or shade class as described below (*adapted from the CWE process, IDL, 2000)*. For example, if we estimate that canopy cover for a particular stretch of stream is somewhere between 50% and 59%, we assign the value of 50% to that section of stream. The estimate is based on a general intuitive observation about the kind of vegetation present, its density, and the width of the stream. The typical vegetation type (below) shows the kind of landscape a particular cover class usually falls into for a stream 5 m wide or less. For example, if a section of a 5 m wide stream is identified as 20% cover class, it is usually because it is in agricultural land, meadows, open areas, or clearcuts. However, that does not mean that the 20% cover class cannot occur in shrublands and forests, because it does on wider streams.

Cover class	Typical vegetation type on 5m wide stream
0 = 0 – 9% cover	agricultural land, denuded areas
10 = 10 –19%	ag land, meadows, open areas, clearcuts
20 = 20 – 29%	ag land, meadows, open areas, clearcuts
30 = 30 – 39%	ag land, meadows, open areas, clearcuts
40 = 40 – 49%	shrublands/meadows

50 = 50 – 59%	shrublands/meadows, open forests
60 = 60 – 69%	shrublands/meadows, open forests
70 = 70 – 79%	forested and headwaters areas
80 = 80 – 89%	forested and headwaters areas
90 = 90 –100%	forested and headwaters areas

It is important to note that the visual estimates made from the aerial photos are strongly influenced by canopy cover. It is not always possible to visualize or anticipate shade characteristics resulting from topography and landform. We assume that canopy coverage and shade are similar based on research conducted by Oregon DEQ. The visual estimates of 'shade' in this TMDL were field verified with a solar pathfinder. The pathfinder measures effective shade and is taking into consideration other physical features that block the sun from hitting the stream surface (e.g. hillsides, canyon walls, terraces, man-made structures). The estimate of 'shade' made visually from an aerial photo does not always take into account topography or any shading that may occur from physical features other than vegetation. However, research has shown that shade and cover measurements are remarkably similar (OWEB, 2001), reinforcing the idea that riparian vegetation and objects proximal to the stream provide the most shade.

Stream Morphology

Measures of current bankfull width or near stream disturbance zone width may not reflect widths that were present under PNV. As impacts to streams and riparian areas occur, width-to-depth ratios tend to increase such that streams become wider and shallower. Shadow length produced by vegetation covers a lower percentage of the water surface in wider streams, and widened streams can also have less vegetative cover if shoreline vegetation has been eroded away.

Shade target selection, which involves evaluating the amount of shade provided at PNV conditions, necessitates recognition of potential natural stream widths as well. In this TMDL appropriate stream widths for shade target selection were determined from analysis of existing stream widths and the relationship between drainage area and bankfull width on regional curves (Rosgen, 1996).

The only factor not developed from the aerial photo work presented above is channel width (i.e., NSDZ or Bankfull Width). Accordingly, this parameter must be estimated from available information. We use two figures to try to estimate bankfull width from drainage area size. The first figure (Figure 1) was developed by Peter Lienenbach of EPA for the Crooked Creek TMDL (IDEQ, 2002). The second figure (Figure 2) consulted is a combination of regional curves published by various researchers and combined by Rosgen (1996).

For each stream evaluated in the loading analysis, natural bankfull width is estimated based on drainage area using these two figures. Additionally, existing width is evaluated from available data. If the stream's existing width is wider than that predicted by these two figures, then the Figure estimate of bankfull width is used in the loading analysis. If existing width is smaller, then existing width is used in the loading analysis.

Figure 1. Bankfull Width as a Function of Width to Depth Ratio and Drainage Area

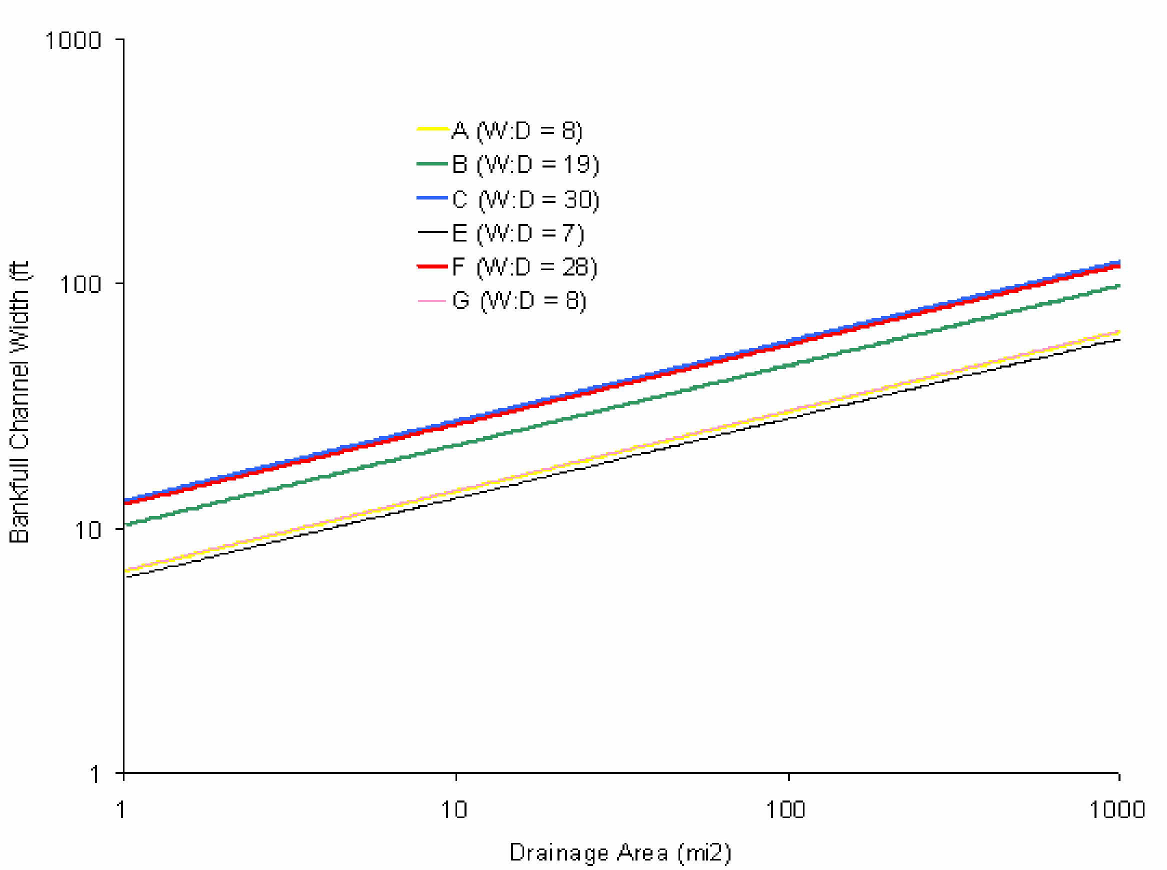
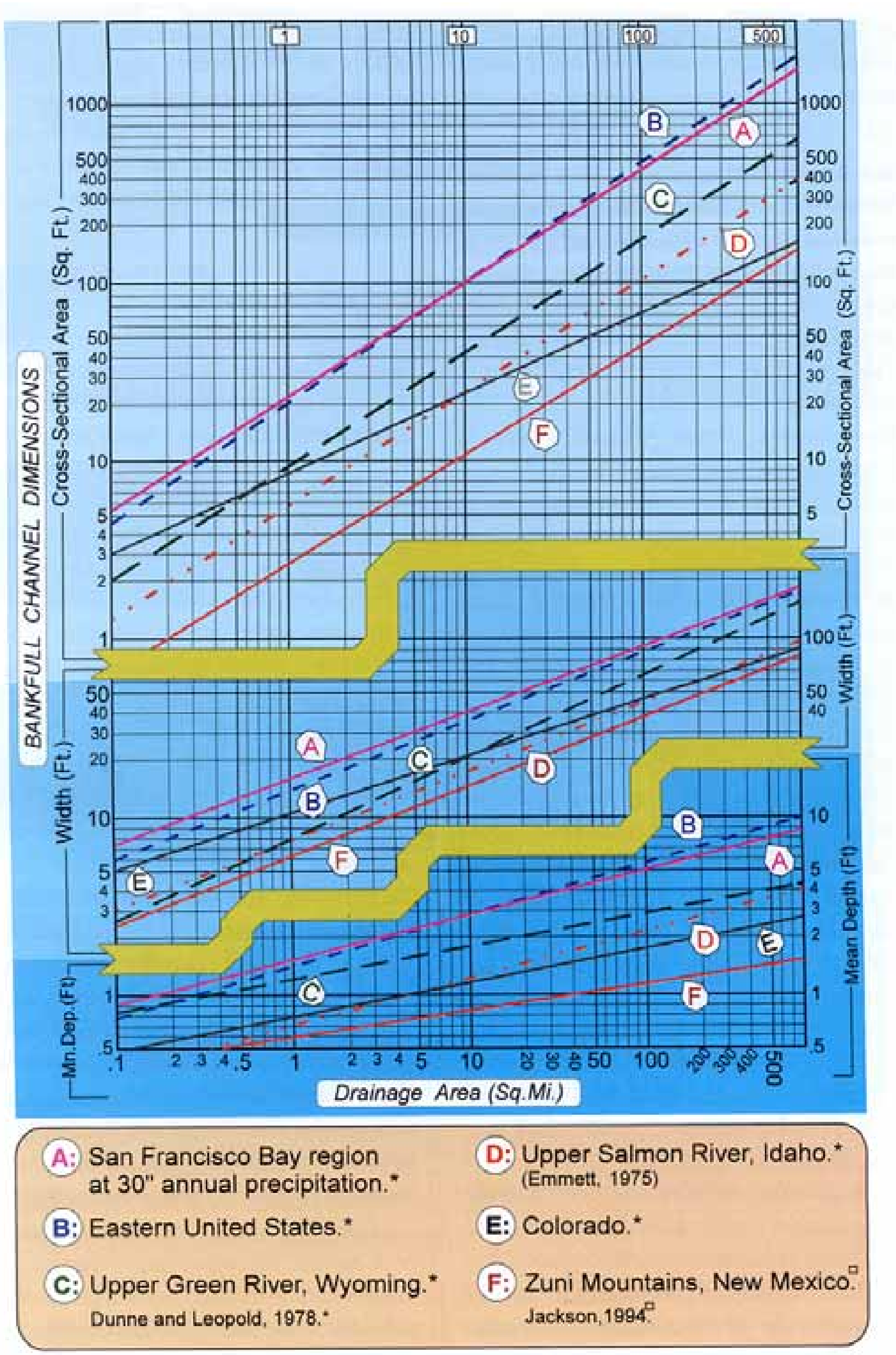


Figure 2. Bankfull Channel Dimensions as a Function of Drainage Area (Rosgen, 1996).



Natural stream widths were first determined for all streams from regional curves. Then upper Trestle Creek in the adjacent Pend Oreille subbasin was used as an example of near natural conditions to test the regional curve estimates. Stream widths were estimated from regional curves for Trestle Creek and compared to existing stream width data for Trestle Creek. The rating curve estimates were consistently 35% lower than actual stream widths in Trestle Creek. Hence all natural stream widths for all streams in the Lower Clark Fork analysis determined by regional curves were corrected by increasing each estimate by 35%.

Resulting natural stream widths on the forested tributaries vary from 2m wide in the headwaters to 54m wide at the mouth of Lightning Creek. (Note: Existing stream widths at the mouth of Lightning Creek may be as high as 180m.) Tributary streams in the lowland areas (primarily on the south side of the Clark Fork River) have natural stream widths that vary from 7m where forested tributaries enter lowlands to 40m at backwater areas adjacent to Pend Oreille Lake.

Design Conditions

Forested Tributaries

The forest tributaries include the Lightning Creek drainage, the Johnson Creek drainage, Gold Creek, WF Blue Creek, Dry Creek, and the upper portions of Twin Creek, Derr Creek, Mosquito Creek, and an unnamed tributary near Cabinet. Soils are assumed to be primarily glacial tills with finer grained glaciofluvial or glaciolacustrine deposits in valley bottoms and lower slope reaches (PWA, 2004). The soil survey of Bonner County suggests that the bulk of the soils on lower slopes are of the Pend Oreille-Treble complex on deep, well drained rolling to steep foothills and mountainsides, although other soils such as Colburn and Capehorn on glacial outwash, alluvial and low floodplain terraces may occur at lower elevations (Weisel, 1982). The soil survey suggests that the vegetation type was based on mixed conifer species such as western red cedar (*Thuja plicata*), western white pine (*Pinus monticola*), grand fir (*Abies grandis*), and Douglas fir (*Psuedotsuga menziesii*) (Weisel, 1982). Other conifers such as western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*) and ponderosa pine (*Pinus ponderosa*) may be locally important. PWA (2004) indicated that riparian areas and floodplains throughout the lower Pend Oreille basin historically supported old growth stands of western redcedar. In Lightning Creek, at lower elevations the dominant species is western hemlock (*Tsuga heterophylla*) with western redcedar in moist to wet areas and grand fir on dry, warm slopes (PWA, 2004). Black cottonwood (*Populus trichocarpa*) and western white pine were also locally important. At higher elevations in the watershed, subalpine fir (*Abies lasiocarpa*) and mountain hemlock (*Tsuga mertensiana*) were dominant (PWA, 2004). Shrub communities in riparian areas were dominated by alders (*Alnus spp*.) and willows (*Salix spp*.) (PWA, 2004).

One mixed conifer (western redcedar and others) vegetation type is assumed for all forested tributaries with the exception of several small forest meadows on Gold Creek, which is addressed separately.

Lower Clark Fork River and Associated Low Gradient Stream Sections

The predominant soils along the Lower Clark Fork River are (from east to west) Pend Oreille silt loam, Bonner silt loam, and Colburn very fine sandy loam (Weisel, 1982). Of these, only the Colburn soil has any agricultural value. Other soils are represented in this area in smaller patches including Mission, Vay, Hoodoo, Treble, and Wrencoe. With the exception of Hoodoo soils which may have been largely meadow grass dominated, all of these soils were likely dominated by conifers such as western redcedar, western white pine, grand fir, and Douglas fir.

It is not known to what extent deciduous vegetation like cottonwoods or alders played a role in the natural riparian vegetation along the Lower Clark Fork River. However, many of the low lying areas along the Clark Fork that have been cleared for hay and pasture or other uses tend to have dense, deciduous shrubby vegetation returning to riparian areas that may preclude the development of coniferous vegetation (Weisel, 1982).

A forest/shrub vegetation type with a mixture of deciduous and conifer vegetation is assumed for the lowland areas of several tributaries (e.g. Twin, Derr, and Mosquito Creeks). Along the Lower Clark Fork River mixed deciduous/conifer forest vegetation type is assumed to be natural. The river may originally have been bordered by conifers, however heights and densities, and thus shade, are likely to be similar for a mixed forest type as well.

Target Selection

To determine potential natural vegetation shade targets for all streams, effective shade curves from several existing temperature TMDLs were examined. These TMDLs are described in this section and were chosen because they used vegetation community modeling to produce these shade curves. For the two vegetation types described above (forested tributaries and forest/shrub mix) curves for the most similar vegetation type were selected for shade target determinations. Because no two landscapes are exactly the same, shade targets were derived by taking an average of the various shade curves available to approximate the shade provided by the vegetative communities in the Lower Clark Fork subbasin. Effective shade curves include percent shade on the vertical axis and stream width on the horizontal axis. As a stream becomes wider, a given vegetation community provides less shade.

The effective shade calculations are based on a six month period from April through September. This coincides with the critical time period when temperatures affect beneficial uses, which typically occur in April through June and again in September when spring and fall salmonids spawning temperatures criteria may be exceeded, and in July and August when cold water aquatic life criteria may be exceeded. Late July and early August typically represent a period of highest stream temperatures. Solar gains can begin early in the spring and affect not only the highest temperatures reached later on in the summer, but solar loadings affect salmonids spawning temperatures in spring and fall. Thus, solar loading in these streams is evaluated from spring (April) to early fall (September). While bull trout are known to spawn into October, the TMDL was created for the times when these streams are most likely to exceed temperature standards.

Forest Tributaries

For forested tributaries an attempt was made to match a western redcedar vegetation type. Four effective shade curves from the following three TMDLs were used:

1) South Fork Clearwater River (IDEQ, 2004) VRU 8 (stream breaklands, cedar and grand fir),

2) South Fork Clearwater River (IDEQ, 2004) VRU 10 (uplands, alder, grand fir, and subalpine fir),

3) Mattole River (CRWQCB, 2002) redwood forest,

4) Willamette Basin (ODEQ, 2004a) Qalc (80% forest, ht.=88.2ft., density=71%).

Although these TMDLs reflect a wide variety of geomorphologies and topographies, effective shades at the same stream width were remarkably similar (Table 1). Although the Mattole River redwood shade curve is consistently higher at most stream widths, when averaged with the other shade curves it compensates for large old growth trees that may have occurred in the Pend Oreille Basin.

Table 1. Effective Shade Targets for the Forested Tributaries Vegetation Type.

Effective Shade Curves	Stream Width (m)													
	2	4	5	8	10	12	14	18	19	21	24	28	40	54
VRU 8	95	92	89	85	81	75	72	65	63	58	56	49	40	31
VRU 10	90	89	80	73	68	62	54	45	46	42	39	35	36	20
Mattole River	92	92	92	91	90	89	87	84	83	82	78	75	64	52
Willamette Basin	94	88	86	81	77	73	64	55	54	52	49	44	38	30
Target Class (%)	**90**	**90**	**80**	**80**	**80**	**70**	**70**	**60**	**60**	**50**	**50**	**50**	**40**	**30**

The forested meadow vegetation type occurred in one small area on Gold Creek , thus was not developed as a separate vegetation type. Stream widths in the area were relatively narrow and these areas would have received a 90% target class based on the Forest Tributaries vegetation type. To compensate for the open meadow nature of these areas on Gold Creek the target class was adjusted to 70% for those areas.

<u>Forest/Shrub Mix</u>

For the forest/shrub mix vegetation type at lower elevations a variety of deciduous and conifer mixes were selected as representative shade curves. Again four shade curves from the following four TMDLs were selected:

1) Alvord Lake (ODEQ, 2003) black cottonwood-pacific willow community,
2) Walla Walla River (ODEQ, 2004b) deciduous-conifer zone,
3) Mattole River (CRWQCB, 2002) mixed hardwood-conifer forest,
4) Willamette Basin (ODEQ, 2004a) Qalf (52% forest, ht.=57.5ft., density=68%).

Again, the Mattole River TMDL shade curve tends to have the highest values, and compensates for the higher moisture regime present in the Pend Oreille Basin. Forest/Shrub mix shade targets for needed stream widths are presented in Table 2.

Table 2. Effective Shade Targets for the Forest/Shrub Mix Vegetation Type.

Effective Shade Curves	Stream Width (m)			
	7	8	11	40
Alvord Lake	62	64	51	-
Walla Walla	86	85	78	25
Mattole River	91	89	86	31
Willamette	67	65	53	23
Target Class (%)	**70**	**70**	**60**	**20**

Monitoring Points

Effective shade monitoring can take place on any reach throughout the Lower Clark Fork Subbasin watersheds and compared to estimates of existing shade seen on Figure 3 and described in Tables 4 through 30. Those areas with the lowest existing shade estimates should be monitored with solar pathfinders to verify the existing shade levels and to determine progress towards meeting shade targets. It is important to note that many existing shade estimates have not been field verified, and may require adjustment during the implementation process. Stream segments for each change in existing shade vary in length depending on land use or landscape that has affected that shade level. It is appropriate to monitor within a given existing shade segment to see if that segment has increased its existing shade towards target levels. Five to ten equally spaced solar pathfinder measurements within that segment should suffice to determine new shade levels in the future.

5.2b Load Capacity Temperature

The loading capacity for a stream under PNV is essential the solar loading allowed under the shade targets specified for the reaches within that stream (Figure 4). These loads are determined by multiplying the solar load to a flat plate collector (under full sun) for a given period of time by the fraction of the solar radiation that is not blocked by shade (i.e. the percent open or 1-percent shade). In other words, if a shade target is 60% (or 0.6), then the solar load hitting the stream under that target is 40% of the load hitting the flat plate collector under full sun.

We obtained solar load data for flat plate collectors from National Renewable Energy Laboratory (NREL) weather stations near by. In this case, an average of two NREL weather stations is used, one at Spokane, WA and the other at Kalispell, MT. The solar loads used in this TMDL are spring/summer averages, thus, we use an average load for the six month period from April through September. These months coincide with time of year that stream temperatures are increasing and when deciduous vegetation is in leaf. Tables 4 through 30 show the PNV shade targets (identified as Target or Potential Shade) and their corresponding potential summer load (in kWh/m^2/day and kWh/day) that serve as the loading capacities for the streams.

5.3b Estimates of Existing Pollutant Loads Temperature

Regulations allow that loadings "...may range from reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting the loading," (Water quality planning and management, 40 CFR § 130.2(I)). An estimate must be made for each point source. Nonpoint sources are typically estimated based on the type of sources (land use) and area (such as a subwatershed), but may be aggregated by type of source or land area. To the extent possible, background loads should be distinguished from human-caused increases in nonpoint loads.

Existing loads in this temperature TMDL come from estimates of existing shade as determined from aerial photo interpretations (Figure 3). Like target shade, existing shade was converted to a solar load by multiplying the fraction of open stream by the solar radiation measured on a flat plate collector at the NREL weather stations. Existing shade data are presented in Tables 4 through 30. Existing shade on Lightning Creek varies from the 0% class at the mouth to 90% class in the headwaters (Table 4). Existing shade on the remainder of the forested portions of tributaries (green color on table) generally varies from 60% class to 90% class (Tables 5 through 30). Existing shade for forest/shrub mix areas (tan color on tables) can vary anywhere from 0% to the 90% class (Tables 22, 27, 28, & 30).

The locations where solar pathfinder data were taken for field verification are shown on the tables in light purple or rose color. The field verification resulted in little changes in the overall existing shade estimates. The average of the solar pathfinder results was consistent with the average of the matching aerial photo estimates (Table 3). Only those stream sections where pathfinder data were taken were corrected based on that data. All other stream sections were assumed to average out, however, that does not preclude that some stream sections may have aerial photo estimates that are incorrect.

Table 3. Solar Pathfinder Field Verification Results

aerial	pathfinder	pathfinder		
class	actual	class	Delta	
70	67.9	60	10	
90	90.9	90	0	
80	56.9	50	30	
40	54.1	50	-10	
90	91.9	90	0	
80	86.9	80	0	
70	90.8	90	-20	
80	87.6	80	0	
0	7.1	0	0	
10	25.7	20	-10	
90	78.5	70	20	
10	50.3	50	-40	
90	73.3	70	20	
70	71.3	70	0	
60	68.4	60	0	
62	67	62	0	average

Like loading capacities (potential loads), existing loads in Tables 3 through 30 are presented on an area basis (kWh/m^2/day) in the upper half of the table and as a total load (kWh/day) in the lower half of the table.

Table 4. Existing and Potential Solar Loads for Lightning Creek.

Segment Length (~miles)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	
0.15	0.9	0.55	0.9	0.55	0.00	
0.15	0.8	1.1	0.9	0.55	-0.55	
0.6	0.9	0.55	0.9	0.55	0.00	
0.1	0.7	1.65	0.8	1.10	-0.55	
1.8	0.7	1.65	0.8	1.10	-0.55	pathfinder = 73.3%
0.25	0.7	1.65	0.7	1.65	0.00	
0.35	0.6	2.2	0.7	1.65	-0.55	
0.4	0.7	1.65	0.7	1.65	0.00	ab Moose
0.25	0.6	2.2	0.7	1.65	-0.55	
0.45	0.7	1.65	0.7	1.65	0.00	
0.6	0.8	1.1	0.7	1.65	0.55	ab Quartz
0.6	0.7	1.65	0.6	2.20	0.55	
0.9	0.6	2.2	0.6	2.20	0.00	ab Rattle
3.7	0.5	2.75	0.6	2.20	-0.55	pathfinder = 50.3%
1.45	0.2	4.4	0.5	2.75	-1.65	
3	0.4	3.3	0.5	2.75	-0.55	ab EF
5.3	0.2	4.4	0.5	2.75	-1.65	pathfinder = 25.7%
3.5	0	5.5	0.3	3.85	-1.65	pathfinder = 7.1%
Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
241.4	724	398	3	398	0	
241.4	724	797	3	398	-398	
965.6	2897	1593	3	1593	0	
160.9	805	1328	5	885	-443	
2896.8	14484	23899	5	15933	-7966	ab Gem
402.3	4426	7302	11	7302	0	
563.3	6196	13631	11	10223	-3408	
643.7	7081	11684	11	11684	0	ab Moose
402.3	5633	12392	14	9294	-3098	
724.2	10139	16729	14	16729	0	
965.6	13518	14870	14	22306	7435	ab Quartz
965.6	15450	25492	16	33989	8497	
1448.4	23175	50984	16	50984	0	ab Rattle
5954.6	113137	311126	19	248901	-62225	ab Wellington
2333.5	56005	246423	24	154014	-92409	
4828.0	115873	382380	24	318650	-63730	ab EF
8529.5	238827	1050837	28	656773	-394064	ab Cascade
5632.7	304166	1672913	54	1171039	-501874	Cascade to mouth
Total	**933259**	**3844779**		**2731097**	**-1113682**	**-29**
						% Reduction

Lightning Creek Tributaries

Table 5. Existing and Potential Solar Loads for Gordon Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
530	0.7	1.65	0.9	0.55	-1.10	
450	0.4	3.3	0.9	0.55	-2.75	
1730	0.8	1.1	0.9	0.55	-0.55	
155	0.7	1.65	0.9	0.55	-1.10	Tributary
200	0.8	1.1	0.9	0.55	-0.55	Tributary
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
530	530.00	874.50	1	291.50	-583.00	
450	1350.00	4455.00	3	742.50	-3712.50	
1730	6920.00	7612.00	4	3806.00	-3806.00	
155	155.00	255.75	1	85.25	-170.50	Tributary
200	600.00	660.00	3	330.00	-330.00	Tributary
Total	**9555.00**	**13857.25**		**5255.25**	**-8602.00**	**-62**
						% Reduction

Table 6. Existing and Potential Solar Loads for Gem Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
135	0.7	1.65	0.9	0.55	-1.10	
550	0.8	1.1	0.9	0.55	-0.55	
1630	0.7	1.65	0.9	0.55	-1.10	
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
135	135.00	222.75	1	74.25	-148.50	
550	550.00	605.00	1	302.50	-302.50	
1630	4890.00	8068.50	3	2689.50	-5379.00	
Total	**5575.00**	**8896.25**		**3066.25**	**-5830.00**	**-66 % Reduction**

Table 7. Existing and Potential Solar Loads for Lunch Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load ($kWh/m^2/day$)	Target or Potential Shade (fraction)	Potential Summer Load ($kWh/m^2/day$)	Potential Load minus Existing load ($kWh/m^2/day$)	
440	0.7	1.65	0.9	0.55	-1.10	
470	0.6	2.2	0.9	0.55	-1.65	
486	0.7	1.65	0.9	0.55	-1.10	
182	0.6	2.2	0.9	0.55	-1.65	
295	0.7	1.65	0.9	0.55	-1.10	
350	0.5	2.75	0.9	0.55	-2.20	
395	0.6	2.2	0.9	0.55	-1.65	tributary
480	0.7	1.65	0.9	0.55	-1.10	tributary
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
440	440.00	726.00	1	242.00	-484.00	
470	470.00	1034.00	1	258.50	-775.50	
486	486.00	801.90	1	267.30	-534.60	
182	546.00	1201.20	3	300.30	-900.90	
295	885.00	1460.25	3	486.75	-973.50	
350	1050.00	2887.50	3	577.50	-2310.00	
395	395.00	869.00	1	217.25	-651.75	
480	480.00	792.00	1	264.00	-528.00	
Total	**4752.00**	**9771.85**		**2613.60**	**-7158.25**	**-73 % Reduction**

Table 8. Existing and Potential Solar Loads for Moose Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)
2300	0.8	1.1	0.9	0.55	-0.55
1240	0.6	2.2	0.9	0.55	-1.65
170	0.4	3.3	0.9	0.55	-2.75
150	0.7	1.65	0.9	0.55	-1.10
865	0.8	1.1	0.8	1.10	0.00
125	0.7	1.65	0.8	1.10	-0.55
35	0.6	2.2	0.8	1.10	-1.10
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
2300	2300.00	2530.00	1	1265.00	-1265.00
1240	4960.00	10912.00	4	2728.00	-8184.00
170	680.00	2244.00	4	374.00	-1870.00
150	600.00	990.00	4	330.00	-660.00
865	4325.00	4757.50	5	4757.50	0.00
125	875.00	1443.75	7	962.50	-481.25
35	245.00	539.00	7	269.50	-269.50
Total	**13985.00**	**23416.25**		**10686.50**	**-12729.75**

-54
% Reduction

Table 9. Existing and Potential Solar Loads for Quartz Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
310	0.8	1.1	0.9	0.55	-0.55	tributary
178	0.9	0.55	0.9	0.55	0.00	tributary
405	0.8	1.1	0.9	0.55	-0.55	tributary
55	0.6	2.2	0.9	0.55	-1.65	tributary
270	0.7	1.65	0.9	0.55	-1.10	tributary
590	0.9	0.55	0.9	0.55	0.00	tributary
1950	0.9	0.55	0.9	0.55	0.00	
1380	0.7	1.65	0.8	1.10	-0.55	
300	0.8	1.1	0.8	1.10	0.00	

Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
310	310.00	341.00	1	170.50	-170.50	
178	178.00	97.90	1	97.90	0.00	
405	405.00	445.50	1	222.75	-222.75	
55	165.00	363.00	3	90.75	-272.25	
270	810.00	1336.50	3	445.50	-891.00	
590	1770.00	973.50	3	973.50	0.00	
1950	5850.00	3217.50	3	3217.50	0.00	
1380	6900.00	11385.00	5	7590.00	-3795.00	
300	1500.00	1650.00	5	1650.00	0.00	
Total	**17888.00**	**19809.90**		**14458.40**	**-5351.50**	**-27 % Reduction**

Table 10. Existing and Potential Solar Loads for Deer Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target/ Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
450	0.7	1.65	0.9	0.55	-1.10	
610	0.8	1.1	0.9	0.55	-0.55	
1440	0.9	0.55	0.9	0.55	0.00	
330	0.7	1.65	0.9	0.55	-1.10	
380	0.8	1.1	0.9	0.55	-0.55	
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
450	450.00	742.50	1	247.50	-495.00	
610	1830.00	2013.00	3	1006.50	-1006.50	
1440	4320.00	2376.00	3	2376.00	0.00	
330	1320.00	2178.00	4	726.00	-1452.00	
380	1520.00	1672.00	4	836.00	-836.00	
Total	**9440.00**	**8981.50**		**5192.00**	**-3789.50**	**-42**
						% Reduction

Table 11. Existing and Potential Solar Loads for Fall, Sheep, and Bear Creeks.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target/ Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
1825	0.7	1.65	0.9	0.55	-1.10	Fall
410	0.9	0.55	0.9	0.55	0.00	
310	0.8	1.1	0.9	0.55	-0.55	Sheep
1000	0.9	0.55	0.9	0.55	0.00	
620	0.8	1.1	0.9	0.55	-0.55	
340	0.9	0.55	0.9	0.55	0.00	
1250	0.7	1.65	0.9	0.55	-1.10	Bear
420	0.9	0.55	0.9	0.55	0.00	
520	0.7	1.65	0.9	0.55	-1.10	
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
1825	5475.00	9033.75	3	3011.25	-6022.50	
410	1640.00	902.00	4	902.00	0.00	
310	310.00	341.00	1	170.50	-170.50	
1000	3000.00	1650.00	3	1650.00	0.00	
620	2480.00	2728.00	4	1364.00	-1364.00	
340	1360.00	748.00	4	748.00	0.00	
1250	3750.00	6187.50	3	2062.50	-4125.00	
420	1680.00	924.00	4	924.00	0.00	
520	2080.00	3432.00	4	1144.00	-2288.00	
Total	**21775.00**	**25946.25**		**11976.25**	**-13970.00**	**-54**
						% Reduction

Table 12. Existing and Potential Solar Loads for Rattle Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
1665	0.7	1.65	0.9	0.55	-1.10	pathfinder = 71.3%
510	0.8	1.1	0.9	0.55	-0.55	tributary
1370	0.8	1.1	0.9	0.55	-0.55	tributary
70	0.8	1.1	0.9	0.55	-0.55	tributary
330	0.9	0.55	0.9	0.55	0.00	tributary
390	0.8	1.1	0.9	0.55	-0.55	tributary
820	0.7	1.65	0.9	0.55	-1.10	tributary
440	0.8	1.1	0.9	0.55	-0.55	tributary
410	0.7	1.65	0.9	0.55	-1.10	tributary
90	0.6	2.2	0.9	0.55	-1.65	tributary
160	0.8	1.1	0.9	0.55	-0.55	tributary
990	0.7	1.65	0.9	0.55	-1.10	tributary
380	0.8	1.1	0.9	0.55	-0.55	tributary
725	0.7	1.65	0.9	0.55	-1.10	tributary
420	0.8	1.1	0.9	0.55	-0.55	tributary
270	0.7	1.65	0.9	0.55	-1.10	tributary
890	0.8	1.1	0.9	0.55	-0.55	tributary
440	0.7	1.65	0.9	0.55	-1.10	tributary
185	0.8	1.1	0.9	0.55	-0.55	tributary
460	0.6	2.2	0.9	0.55	-1.65	tributary
100	0.7	1.65	0.9	0.55	-1.10	tributary
260	0.7	1.65	0.9	0.55	-1.10	tributary
450	0.8	1.1	0.9	0.55	-0.55	tributary
840	0.7	1.65	0.9	0.55	-1.10	tributary
960	0.6	2.2	0.9	0.55	-1.65	tributary
150	0.5	2.75	0.9	0.55	-2.20	tributary
580	0.8	1.1	0.9	0.55	-0.55	tributary
630	0.6	2.2	0.9	0.55	-1.65	pathfinder = 68.4%
2770	0.7	1.65	0.9	0.55	-1.10	
300	0.8	1.1	0.9	0.55	-0.55	
1275	0.7	1.65	0.8	1.10	-0.55	
960	0.8	1.1	0.8	1.10	0.00	
1430	0.7	1.65	0.8	1.10	-0.55	
490	0.8	1.1	0.8	1.10	0.00	
230	0.6	2.2	0.8	1.10	-1.10	pathfinder = 67.9%

Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
1665	1665.00	2747.25	1	915.75	-1831.50
510	1530.00	1683.00	3	841.50	-841.50
1370	1370.00	1507.00	1	753.50	-753.50
70	210.00	231.00	3	115.50	-115.50
330	990.00	544.50	3	544.50	0.00

390	1170.00	1287.00	3	643.50	-643.50	
820	3280.00	5412.00	4	1804.00	-3608.00	
440	1760.00	1936.00	4	968.00	-968.00	
410	1640.00	2706.00	4	902.00	-1804.00	
90	360.00	792.00	4	198.00	-594.00	
160	160.00	176.00	1	88.00	-88.00	
990	2970.00	4900.50	3	1633.50	-3267.00	
380	1140.00	1254.00	3	627.00	-627.00	
725	725.00	1196.25	1	398.75	-797.50	
420	1260.00	1386.00	3	693.00	-693.00	
270	810.00	1336.50	3	445.50	-891.00	
890	890.00	979.00	1	489.50	-489.50	
440	1320.00	2178.00	3	726.00	-1452.00	
185	185.00	203.50	1	101.75	-101.75	
460	1380.00	3036.00	3	759.00	-2277.00	
100	300.00	495.00	3	165.00	-330.00	
260	260.00	429.00	1	143.00	-286.00	
450	450.00	495.00	1	247.50	-247.50	
840	2520.00	4158.00	3	1386.00	-2772.00	
960	2880.00	6336.00	3	1584.00	-4752.00	
150	600.00	1650.00	4	330.00	-1320.00	
580	2320.00	2552.00	4	1276.00	-1276.00	
630	630.00	1386.00	1	346.50	-1039.50	
2770	8310.00	13711.50	3	4570.50	-9141.00	
300	1200.00	1320.00	4	660.00	-660.00	
1275	6375.00	10518.75	5	7012.50	-3506.25	
960	6720.00	7392.00	7	7392.00	0.00	
1430	11440.00	18876.00	8	12584.00	-6292.00	
490	4410.00	4851.00	9	4851.00	0.00	
230	2070.00	4554.00	9	2277.00	-2277.00	
Total	**75300.00**	**114215.75**		**58473.25**	**-55742.50**	**-49**
						% Reduction

Table 13. Existing and Potential Solar Loads for Wellington Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load ($kWh/m^2/day$)	Target or Potential Shade (fraction)	Potential Summer Load ($kWh/m^2/day$)	Potential Load minus Existing load ($kWh/m^2/day$)	
1200	0.9	0.55	0.9	0.55	0.00	SF
480	0.8	1.1	0.9	0.55	-0.55	SF
400	0.7	1.65	0.9	0.55	-1.10	SF
1040	0.6	2.2	0.9	0.55	-1.65	SF
210	0.9	0.55	0.9	0.55	0.00	SF
210	0.6	2.2	0.9	0.55	-1.65	tributary
580	0.7	1.65	0.9	0.55	-1.10	tributary
1300	0.7	1.65	0.9	0.55	-1.10	tributary
800	0.8	1.1	0.9	0.55	-0.55	tributary
600	0.9	0.55	0.9	0.55	0.00	tributary
620	0.6	2.2	0.9	0.55	-1.65	
630	0.7	1.65	0.9	0.55	-1.10	
1570	0.8	1.1	0.9	0.55	-0.55	
470	0.9	0.55	0.9	0.55	0.00	
240	0.8	1.1	0.9	0.55	-0.55	
890	0.9	0.55	0.8	1.10	0.55	
90	0.8	1.1	0.8	1.10	0.00	
160	0.9	0.55	0.8	1.10	0.55	
150	0.8	1.1	0.8	1.10	0.00	
120	0.7	1.65	0.8	1.10	-0.55	
550	0.9	0.55	0.8	1.10	0.55	
1550	0.8	1.1	0.8	1.10	0.00	
450	0.9	0.55	0.8	1.10	0.55	pathfinder = 90.9%
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
1200	1200	660	1	660	0	
480	1440	1584	3	792	-792	
400	1200	1980	3	660	-1320	
1040	4160	9152	4	2288	-6864	
210	1050	578	5	578	0	
210	210	462	1	116	-347	
580	580	957	1	319	-638	
1300	3900	6435	3	2145	-4290	
800	3200	3520	4	1760	-1760	
600	2400	1320	4	1320	0	
620	620	1364	1	341	-1023	
630	630	1040	1	347	-693	
1570	4710	5181	3	2591	-2591	
470	1880	1034	4	1034	0	
240	960	1056	4	528	-528	
890	6230	3427	7	6853	3427	
90	630	693	7	693	0	

160	1120	616	7	1232	616	
150	1050	1155	7	1155	0	
120	960	1584	8	1056	-528	
550	4400	2420	8	4840	2420	
1550	13950	15345	9	15345	0	
450	4050	2228	9	4455	2228	
Total	**60530**	**63789**		**51106**	**-12683**	**-20**
						% Reduction

Table 14. Existing and Potential Solar Loads for Mud, Steep, Silvertip, and Trapper Creeks and Several Unnamed Tributaries.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load ($kWh/m^2/day$)	Target or Potential Shade (fraction)	Potential Summer Load ($kWh/m^2/day$)	Potential Load minus Existing load ($kWh/m^2/day$)	
395	0.6	2.2	0.9	0.55	-1.65	Mud
245	0.8	1.1	0.9	0.55	-0.55	Mud
1000	0.7	1.65	0.9	0.55	-1.10	Mud
143	0.6	2.2	0.9	0.55	-1.65	Mud
690	0.7	1.65	0.9	0.55	-1.10	Mud
138	0.2	4.4	0.9	0.55	-3.85	Mud
540	0.8	1.1	0.9	0.55	-0.55	Steep
390	0.7	1.65	0.9	0.55	-1.10	Steep
430	0.8	1.1	0.9	0.55	-0.55	Steep
770	0.9	0.55	0.9	0.55	0.00	Steep
425	0.8	1.1	0.9	0.55	-0.55	Steep/unnamed
750	0.7	1.65	0.9	0.55	-1.10	Steep/unnamed
550	0.8	1.1	0.9	0.55	-0.55	Steep/unnamed
293	0.9	0.55	0.9	0.55	0.00	Steep/unnamed
245	0.6	2.2	0.9	0.55	-1.65	unnamed
665	0.7	1.65	0.9	0.55	-1.10	unnamed
510	0.6	2.2	0.9	0.55	-1.65	unnamed
273	0.9	0.55	0.9	0.55	0.00	unnamed
260	0.7	1.65	0.9	0.55	-1.10	unnamed
760	0.7	1.65	0.9	0.55	-1.10	Silvertip
885	0.8	1.1	0.9	0.55	-0.55	Silvertip
495	0.9	0.55	0.9	0.55	0.00	Silvertip
485	0.7	1.65	0.9	0.55	-1.10	Silvertip
490	0.5	2.75	0.9	0.55	-2.20	Trapper
1110	0.7	1.65	0.9	0.55	-1.10	Trapper
1000	0.8	1.1	0.9	0.55	-0.55	Trapper
180	0.3	3.85	0.9	0.55	-3.30	Trapper
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
395	395	869	1	217	-652	
245	245	270	1	135	-135	
1000	3000	4950	3	1650	-3300	
143	429	944	3	236	-708	
690	2760	4554	4	1518	-3036	
138	552	2429	4	304	-2125	
540	540	594	1	297	-297	
390	390	644	1	215	-429	
430	1290	1419	3	710	-710	
770	2310	1271	3	1271	0	
425	425	468	1	234	-234	
750	750	1238	1	413	-825	

550	1650	1815	3	908	-908
293	879	483	3	483	0
245	245	539	1	135	-404
665	665	1097	1	366	-732
510	1530	3366	3	842	-2525
273	819	450	3	450	0
260	780	1287	3	429	-858
760	760	1254	1	418	-836
885	885	974	1	487	-487
495	1980	1089	4	1089	0
485	1940	3201	4	1067	-2134
490	490	1348	1	270	-1078
1110	3330	5495	3	1832	-3663
1000	4000	4400	4	2200	-2200
180	720	2772	4	396	-2376
Total	**33759**	**49217**		**18567**	**-30649**

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% Reduction

Table 15. Existing and Potential Solar Loads for Porcupine Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	
480	0.7	1.65	0.9	0.55	-1.10	tributary
620	0.8	1.1	0.9	0.55	-0.55	tributary
355	0.7	1.65	0.9	0.55	-1.10	tributary
150	0.9	0.55	0.9	0.55	0.00	tributary
2310	0.7	1.65	0.9	0.55	-1.10	SF
485	0.9	0.55	0.9	0.55	0.00	SF
245	0.7	1.65	0.9	0.55	-1.10	
700	0.8	1.1	0.9	0.55	-0.55	
550	0.9	0.55	0.9	0.55	0.00	
220	0.7	1.65	0.9	0.55	-1.10	
190	0.8	1.1	0.9	0.55	-0.55	
2190	0.9	0.55	0.8	1.10	0.55	
660	0.5	2.75	0.8	1.10	-1.65	pathfinder = 56.9%
670	0.9	0.55	0.8	1.10	0.55	
320	0.8	1.1	0.8	1.10	0.00	
Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
480	480.00	792.00	1	264.00	-528.00	
620	620.00	682.00	1	341.00	-341.00	
355	1065.00	1757.25	3	585.75	-1171.50	
150	450.00	247.50	3	247.50	0.00	
2310	6930.00	11434.50	3	3811.50	-7623.00	
485	1940.00	1067.00	4	1067.00	0.00	
245	245.00	404.25	1	134.75	-269.50	
700	2100.00	2310.00	3	1155.00	-1155.00	
550	1650.00	907.50	3	907.50	0.00	
220	880.00	1452.00	4	484.00	-968.00	
190	760.00	836.00	4	418.00	-418.00	
2190	15330.00	8431.50	7	16863.00	8431.50	
660	5280.00	14520.00	8	5808.00	-8712.00	
670	5360.00	2948.00	8	5896.00	2948.00	
320	2560.00	2816.00	8	2816.00	0.00	
Total	**45650.00**	**50605.50**		**40799.00**	**-9806.50**	**-19**
						% Reduction

Table 16. Existing and Potential Solar Loads for East Fork Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load ($kWh/m^2/day$)	Target or Potential Shade (fraction)	Potential Summer Load ($kWh/m^2/day$)	Potential Load minus Existing load ($kWh/m^2/day$)		
1025	0.6	2.2	0.9	0.55	-1.65	tributary	
465	0.7	1.65	0.9	0.55	-1.10	tributary	
170	0.8	1.1	0.9	0.55	-0.55	tributary	
225	0.7	1.65	0.9	0.55	-1.10	tributary	
640	0.6	2.2	0.9	0.55	-1.65	tributary	
1090	0.7	1.65	0.9	0.55	-1.10	tributary	
520	0.9	0.55	0.9	0.55	0.00	tributary	
540	0.8	1.1	0.9	0.55	-0.55	tributary	
860	0.9	0.55	0.9	0.55	0.00	tributary	
445	0.7	1.65	0.9	0.55	-1.10	Savage	
1480	0.9	0.55	0.9	0.55	0.00	Savage	
3440	0.9	0.55	0.8	1.10	0.55	Savage	pathfinder = 91.9%
300	0.9	0.55	0.8	1.10	0.55		
480	0.8	1.1	0.8	1.10	0.00		
160	0.5	2.75	0.8	1.10	-1.65		
1390	0.8	1.1	0.7	1.65	0.55		
2460	0.7	1.65	0.7	1.65	0.00		pathfinder = 70.7%
1760	0.1	4.95	0.7	1.65	-3.30		pathfinder = 15.2%

Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
1025	1025	2255	1	564	-1691	
465	1395	2302	3	767	-1535	
170	510	561	3	281	-281	
225	675	1114	3	371	-743	
640	2560	5632	4	1408	-4224	
1090	4360	7194	4	2398	-4796	
520	2600	1430	5	1430	0	
540	2700	2970	5	1485	-1485	
860	4300	2365	5	2365	0	
445	1335	2203	3	734	-1469	
1480	5920	3256	4	3256	0	
3440	24080	13244	7	26488	13244	
300	2700	1485	9	2970	1485	
480	4320	4752	9	4752	0	
160	1440	3960	9	1584	-2376	
1390	15290	16819	11	25229	8410	
2460	29520	48708	12	48708	0	
1760	24640	121968	14	40656	-81312	
Total	**129370**	**242217**		**165446**	**-76772**	**-32**
						% Reduction

Table 17. Existing and Potential Solar Loads for unnamed tributaries to Lightning Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)
970	0.7	1.65	0.9	0.55	-1.10
480	0.6	2.2	0.9	0.55	-1.65
390	0.7	1.65	0.9	0.55	-1.10
2190	0.7	1.65	0.9	0.55	-1.10
1470	0.7	1.65	0.9	0.55	-1.10
380	0.5	2.75	0.9	0.55	-2.20
Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
970	970.00	1600.50	1	533.50	-1067.00
480	1440.00	3168.00	3	792.00	-2376.00
390	1170.00	1930.50	3	643.50	-1287.00
2190	6570.00	10840.50	3	3613.50	-7227.00
1470	4410.00	7276.50	3	2425.50	-4851.00
380	1520.00	4180.00	4	836.00	-3344.00
Total	**16080.00**	**28996.00**		**8844.00**	**-20152.00**

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% Reduction

Table 18. Existing and Potential Solar Loads for Morris Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
240	0.6	2.2	0.9	0.55	-1.65	Tributary
965	0.8	1.1	0.9	0.55	-0.55	Tributary
60	0.9	0.55	0.9	0.55	0.00	Tributary
860	0.9	0.55	0.9	0.55	0.00	
790	0.8	1.1	0.9	0.55	-0.55	
395	0.9	0.55	0.9	0.55	0.00	
160	0.8	1.1	0.9	0.55	-0.55	
170	0.9	0.55	0.9	0.55	0.00	
200	0.8	1.1	0.8	1.10	0.00	
210	0.9	0.55	0.8	1.10	0.55	
2250	0.7	1.65	0.8	1.10	-0.55	pathfinder = 78.5%
Segment Length (meters)	**Segment Area (m^2)**	**Existing Summer Load (kWh/day)**	**Natural Stream Width (m)**	**Potential Summer Load (kWh/day)**	**Potential Load minus Existing Load (kWh/day)**	
240	240	528	1	132	-396	
965	2895	3185	3	1592	-1592	
60	180	99	3	99	0	
860	860	473	1	473	0	
790	2370	2607	3	1304	-1304	
395	1185	652	3	652	0	
160	640	704	4	352	-352	
170	680	374	4	374	0	
200	1000	1100	5	1100	0	
210	1050	578	5	1155	578	
2250	15750	25988	7	17325	-8663	
Total	**26850**	**36286**		**24558**	**-11729**	**-32**
						% Reduction

Table 19. Existing and Potential Solar Loads for Regal Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
420	0.8	1.1	0.9	0.55	-0.55	
340	0.9	0.55	0.9	0.55	0.00	
495	0.8	1.1	0.9	0.55	-0.55	
610	0.9	0.55	0.9	0.55	0.00	unnamed
780	0.6	2.2	0.9	0.55	-1.65	
1120	0.8	1.1	0.9	0.55	-0.55	
810	0.9	0.55	0.9	0.55	0.00	
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
420	420.00	462.00	1	231.00	-231.00	
340	340.00	187.00	1	187.00	0.00	
495	1485.00	1633.50	3	816.75	-816.75	
610	1830.00	1006.50	3	1006.50	0.00	
780	780.00	1716.00	1	429.00	-1287.00	
1120	3360.00	3696.00	3	1848.00	-1848.00	
810	3240.00	1782.00	4	1782.00	0.00	
Total	**11455.00**	**10483.00**		**6300.25**	**-4182.75**	**-40**
						% Reduction

Table 20. Existing and Potential Solar Loads for Cascade Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
1111	0.9	0.55	0.9	0.55	0.00	tributary
360	0.8	1.1	0.9	0.55	-0.55	Webb
980	0.9	0.55	0.9	0.55	0.00	Webb
250	0.7	1.65	0.9	0.55	-1.10	Webb
540	0.8	1.1	0.9	0.55	-0.55	Webb
200	0.9	0.55	0.9	0.55	0.00	Webb
210	0.7	1.65	0.9	0.55	-1.10	Webb
220	0.8	1.1	0.9	0.55	-0.55	Webb
440	0.5	2.75	0.9	0.55	-2.20	Webb
410	0.7	1.65	0.9	0.55	-1.10	Webb
240	0.8	1.1	0.9	0.55	-0.55	Webb
260	0.5	2.75	0.9	0.55	-2.20	Webb
80	0.7	1.65	0.9	0.55	-1.10	Webb
435	0.7	1.65	0.9	0.55	-1.10	
370	0.8	1.1	0.9	0.55	-0.55	
1370	0.9	0.55	0.9	0.55	0.00	
220	0.7	1.65	0.9	0.55	-1.10	

1575	0.9	0.55	0.9	0.55	0.00	pathfinder = 90.8%
180	0.5	2.75	0.9	0.55	-2.20	
285	0.7	1.65	0.9	0.55	-1.10	
230	0.3	3.85	0.8	1.10	-2.75	
1020	0.9	0.55	0.8	1.10	0.55	
225	0.5	2.75	0.8	1.10	-1.65	
240	0.7	1.65	0.8	1.10	-0.55	
300	0	5.5	0.8	1.10	-4.40	

Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
1111	3333	1833	3	1833	0	
360	360	396	1	198	-198	
980	980	539	1	539	0	
250	750	1238	3	413	-825	
540	1620	1782	3	891	-891	
200	600	330	3	330	0	
210	630	1040	3	347	-693	
220	660	726	3	363	-363	
440	1760	4840	4	968	-3872	
410	1640	2706	4	902	-1804	
240	960	1056	4	528	-528	
260	1040	2860	4	572	-2288	
80	320	528	4	176	-352	
435	435	718	1	239	-479	
370	370	407	1	204	-204	
1370	4110	2261	3	2261	0	
220	660	1089	3	363	-726	
1575	6300	3465	4	3465	0	
180	720	1980	4	396	-1584	
285	1140	1881	4	627	-1254	
230	1150	4428	5	1265	-3163	
1020	5100	2805	5	5610	2805	
225	1125	3094	5	1238	-1856	
240	1680	2772	7	1848	-924	
300	2100	11550	7	2310	-9240	
Total	**39543**	**56322**		**27884**	**-28438**	**-50**
						% Reduction

Table 21. Existing and Potential Solar Loads for Spring Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
665	0.7	1.65	0.9	0.55	-1.10	tributary
320	0.8	1.1	0.9	0.55	-0.55	tributary
340	0.7	1.65	0.9	0.55	-1.10	tributary
780	0.9	0.55	0.9	0.55	0.00	tributary
300	0.8	1.1	0.9	0.55	-0.55	tributary
380	0.7	1.65	0.9	0.55	-1.10	tributary
350	0.8	1.1	0.9	0.55	-0.55	tributary
450	0.9	0.55	0.9	0.55	0.00	tributary
180	0.8	1.1	0.9	0.55	-0.55	tributary
1770	0.9	0.55	0.9	0.55	0.00	tributary
360	0.7	1.65	0.9	0.55	-1.10	
440	0.8	1.1	0.9	0.55	-0.55	
480	0.7	1.65	0.9	0.55	-1.10	
340	0.8	1.1	0.9	0.55	-0.55	
1450	0.9	0.55	0.9	0.55	0.00	
190	0.7	1.65	0.9	0.55	-1.10	
910	0.9	0.55	0.9	0.55	0.00	
510	0.7	1.65	0.8	1.10	-0.55	
760	0.5	2.75	0.8	1.10	-1.65	
1330	0.9	0.55	0.8	1.10	0.55	
50	0.3	3.85	0.8	1.10	-2.75	
700	0.9	0.55	0.8	1.10	0.55	
40	0.7	1.65	0.8	1.10	-0.55	
290	0.3	3.85	0.8	1.10	-2.75	
220	0.9	0.55	0.8	1.10	0.55	
440	0.4	3.3	0.8	1.10	-2.20	
350	0.9	0.55	0.8	1.10	0.55	
150	0.7	1.65	0.8	1.10	-0.55	
340	0.6	2.2	0.8	1.10	-1.10	
215	0.9	0.55	0.8	1.10	0.55	
160	0.7	1.65	0.8	1.10	-0.55	
220	0.3	3.85	0.8	1.10	-2.75	
235	0.8	1.1	0.8	1.10	0.00	
900	0.9	0.55	0.8	1.10	0.55	
180	0	5.5	0.8	1.10	-4.40	
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
665	665	1097	1	366	-732	
320	320	352	1	176	-176	
340	1020	1683	3	561	-1122	
780	2340	1287	3	1287	0	

300	300	330	1	165	-165	
380	380	627	1	209	-418	
350	1050	1155	3	578	-578	
450	1350	743	3	743	0	
180	540	594	3	297	-297	
1770	7080	3894	4	3894	0	
360	360	594	1	198	-396	
440	440	484	1	242	-242	
480	1440	2376	3	792	-1584	
340	1020	1122	3	561	-561	
1450	4350	2393	3	2393	0	
190	760	1254	4	418	-836	
910	3640	2002	4	2002	0	
510	2550	4208	5	2805	-1403	
760	3800	10450	5	4180	-6270	
1330	9310	5121	7	10241	5121	
50	350	1348	7	385	-963	
700	4900	2695	7	5390	2695	
40	280	462	7	308	-154	
290	2030	7816	7	2233	-5583	
220	1540	847	7	1694	847	
440	3520	11616	8	3872	-7744	
350	2800	1540	8	3080	1540	
150	1200	1980	8	1320	-660	
340	2720	5984	8	2992	-2992	
215	1720	946	8	1892	946	
160	1440	2376	9	1584	-792	
220	1980	7623	9	2178	-5445	
235	2115	2327	9	2327	0	
900	8100	4455	9	8910	4455	
180	1620	8910	9	1782	-7128	
Total	**79030**	**102688**		**72053**	**-30635**	**-30**
						% Reduction

North Side Tributaries

Table 22. Existing and Potential Solar Loads for Mosquito Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	
1070	0.9	0.55	0.9	0.55	0.00	tributary
220	0.2	4.4	0.9	0.55	-3.85	tributary
360	0.7	1.65	0.9	0.55	-1.10	tributary
1190	0.9	0.55	0.9	0.55	0.00	tributary
185	0.8	1.1	0.9	0.55	-0.55	tributary
1260	0.9	0.55	0.9	0.55	0.00	tributary
490	0.7	1.65	0.9	0.55	-1.10	
3185	0.9	0.55	0.9	0.55	0.00	
560	0.8	1.1	0.9	0.55	-0.55	
775	0.9	0.55	0.8	1.10	0.55	
800	0.8	1.1	0.8	1.10	0.00	
1140	0.9	0.55	0.8	1.10	0.55	
245	0.8	1.1	0.8	1.10	0.00	
780	0.9	0.55	0.8	1.10	0.55	
250	0.7	1.65	0.7	1.65	0.00	forest/shrub
260	0.2	4.4	0.7	1.65	-2.75	forest/shrub
280	0.5	2.75	0.7	1.65	-1.10	forest/shrub
1150	0	5.5	0.7	1.65	-3.85	forest/shrub
Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
1070	1070	589	1	589	0	
220	220	968	1	121	-847	
360	1080	1782	3	594	-1188	
1190	3570	1964	3	1964	0	
185	740	814	4	407	-407	
1260	5040	2772	4	2772	0	
490	490	809	1	270	-539	
3185	9555	5255	3	5255	0	
560	2240	2464	4	1232	-1232	
775	3875	2131	5	4263	2131	
800	4000	4400	5	4400	0	
1140	5700	3135	5	6270	3135	
245	1715	1887	7	1887	0	
780	5460	3003	7	6006	3003	
250	1750	2888	7	2888	0	
260	2080	9152	8	3432	-5720	
280	2240	6160	8	3696	-2464	
1150	9200	50600	8	15180	-35420	
Total	**60025**	**100771**		**61223**	**-39548**	**-39**
						% Reduction

Table 23. Existing and Potential Solar Loads for Gold Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	
1040	0.9	0.55	0.9	0.55	0.00	tributary
1415	0.8	1.1	0.9	0.55	-0.55	tributary
190	0.9	0.55	0.9	0.55	0.00	
660	0.7	1.65	0.9	0.55	-1.10	
230	0.9	0.55	0.9	0.55	0.00	
630	0.8	1.1	0.9	0.55	-0.55	
250	0.5	2.75	0.9	0.55	-2.20	
1590	0.8	1.1	0.9	0.55	-0.55	
170	0.6	2.2	0.9	0.55	-1.65	
110	0.3	3.85	0.7	1.65	-2.20	meadow
220	0.2	4.4	0.7	1.65	-2.75	meadow
735	0.3	3.85	0.7	1.65	-2.20	meadow
740	0.7	1.65	0.8	1.10	-0.55	
300	0.6	2.2	0.8	1.10	-1.10	
380	0.5	2.75	0.8	1.10	-1.65	
70	0.1	4.95	0.8	1.10	-3.85	
235	0.5	2.75	0.8	1.10	-1.65	
250	0.3	3.85	0.8	1.10	-2.75	
255	0.1	4.95	0.8	1.10	-3.85	
90	0.2	4.4	0.8	1.10	-3.30	MT
420	0.5	2.75	0.8	1.10	-1.65	MT
125	0.1	4.95	0.8	1.10	-3.85	MT
480	0.8	1.1	0.8	1.10	0.00	MT
160	0.6	2.2	0.8	1.10	-1.10	MT
310	0.7	1.65	0.8	1.10	-0.55	MT
240	0.9	0.55	0.8	1.10	0.55	MT

Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
1040	1040	572	1	572	0
1415	4245	4670	3	2335	-2335
190	190	105	1	105	0
660	660	1089	1	363	-726
230	690	380	3	380	0
630	1890	2079	3	1040	-1040
250	750	2063	3	413	-1650
1590	6360	6996	4	3498	-3498
170	680	1496	4	374	-1122
110	440	1694	4	726	-968
220	1100	4840	5	1815	-3025
735	3675	14149	5	6064	-8085
740	3700	6105	5	4070	-2035

300	2100	4620	7	2310	-2310	
380	2660	7315	7	2926	-4389	
70	490	2426	7	539	-1887	
235	1645	4524	7	1810	-2714	
250	1750	6738	7	1925	-4813	
255	1785	8836	7	1964	-6872	
90	630	2772	7	693	-2079	
420	3360	9240	8	3696	-5544	
125	1000	4950	8	1100	-3850	
480	3840	4224	8	4224	0	
160	1280	2816	8	1408	-1408	
310	2480	4092	8	2728	-1364	
240	1920	1056	8	2112	1056	
Total	**50360**	**109843**		**49187**	**-60657**	**-55**
						% Reduction

Table 24. Existing and Potential Solar Loads for West Fork Blue Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
1590	0.5	2.75	0.9	0.55	-2.20	tributary
300	0.4	3.3	0.9	0.55	-2.75	tributary
380	0.3	3.85	0.9	0.55	-3.30	tributary
3700	0.9	0.55	0.8	1.10	0.55	
420	0.5	2.75	0.7	1.65	-1.10	
690	0.3	3.85	0.7	1.65	-2.20	
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
1590	1590	4373	1	875	-3498	
300	900	2970	3	495	-2475	
380	1140	4389	3	627	-3762	
3700	33300	18315	9	36630	18315	
420	4620	12705	11	7623	-5082	
690	7590	29222	11	12524	-16698	
Total	**49140**	**71973**		**58773**	**-13200**	**-18**
						% Reduction

South Side Tributaries

Table 25. Existing and Potential Solar Loads for Johnson Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	Johnson Creek
1250	0.9	0.55	0.9	0.55	0.00	tributary 1
370	0.8	1.1	0.9	0.55	-0.55	tributary 1
50	0.9	0.55	0.9	0.55	0.00	tributary 1
240	0.8	1.1	0.9	0.55	-0.55	tributary 2
190	0.9	0.55	0.9	0.55	0.00	tributary 2
960	0.8	1.1	0.9	0.55	-0.55	tributary 2
490	0.9	0.55	0.9	0.55	0.00	tributary 2
700	0.8	1.1	0.9	0.55	-0.55	tributary 2
390	0.8	1.1	0.9	0.55	-0.55	tributary 2
260	0.9	0.55	0.9	0.55	0.00	tributary 2
800	0.8	1.1	0.9	0.55	-0.55	tributary 2
640	0.9	0.55	0.9	0.55	0.00	tributary 3
1470	0.8	1.1	0.9	0.55	-0.55	tributary 3
1120	0.9	0.55	0.9	0.55	0.00	tributary 4
160	0.7	1.65	0.9	0.55	-1.10	tributary 4
250	0.8	1.1	0.9	0.55	-0.55	tributary 4
130	0.7	1.65	0.9	0.55	-1.10	tributary 4
380	0.8	1.1	0.9	0.55	-0.55	tributary 4
930	0.9	0.55	0.9	0.55	0.00	tributary 5
530	0.8	1.1	0.9	0.55	-0.55	tributary 5
170	0.6	2.2	0.9	0.55	-1.65	tributary 5
170	0.9	0.55	0.9	0.55	0.00	tributary 5
210	0.8	1.1	0.9	0.55	-0.55	tributary 5
980	0.9	0.55	0.9	0.55	0.00	
1000	0.8	1.1	0.9	0.55	-0.55	
740	0.7	1.65	0.9	0.55	-1.10	
4330	0.8	1.1	0.8	1.10	0.00	pathfinder = 87.6%
400	0.7	1.65	0.7	1.65	0.00	
1570	0.8	1.1	0.7	1.65	0.55	
260	0.6	2.2	0.7	1.65	-0.55	

Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
1250	1250	688	1	688	0
370	1110	1221	3	611	-611
50	150	83	3	83	0
240	240	264	1	132	-132
190	190	105	1	105	0
960	960	1056	1	528	-528
490	1470	809	3	809	0

700	2100	2310	3	1155	-1155	
390	1170	1287	3	644	-644	
260	1040	572	4	572	0	
800	3200	3520	4	1760	-1760	
640	640	352	1	352	0	
1470	4410	4851	3	2426	-2426	
1120	1120	616	1	616	0	
160	480	792	3	264	-528	
250	750	825	3	413	-413	
130	390	644	3	215	-429	
380	1140	1254	3	627	-627	
930	930	512	1	512	0	
530	1590	1749	3	875	-875	
170	510	1122	3	281	-842	
170	510	281	3	281	0	
210	630	693	3	347	-347	
980	980	539	1	539	0	
1000	3000	3300	3	1650	-1650	
740	2960	4884	4	1628	-3256	
4330	38970	42867	9	42867	0	
400	4400	7260	11	7260	0	
1570	17270	18997	11	28496	9499	
260	2860	6292	11	4719	-1573	**% Reduction**
Total	**96420**	**109742**		**101448**	**-8294**	**-8**

Table 26. Existing and Potential Solar Loads for West Johnson Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	West Johnson
230	0.7	1.65	0.9	0.55	-1.10	tributary 1
285	0.6	2.2	0.9	0.55	-1.65	tributary 1
250	0.5	2.75	0.9	0.55	-2.20	tributary 1
120	0.7	1.65	0.9	0.55	-1.10	tributary 1
1150	0.5	2.75	0.9	0.55	-2.20	tributary 1
245	0.8	1.1	0.9	0.55	-0.55	tributary 1
500	0.7	1.65	0.9	0.55	-1.10	tributary 2
560	0.8	1.1	0.9	0.55	-0.55	tributary 2
145	0.7	1.65	0.9	0.55	-1.10	tributary 2
50	0.5	2.75	0.9	0.55	-2.20	tributary 2
365	0.7	1.65	0.9	0.55	-1.10	tributary 3
650	0.8	1.1	0.9	0.55	-0.55	tributary 3
940	0.7	1.65	0.9	0.55	-1.10	tributary 3
50	0.3	3.85	0.9	0.55	-3.30	tributary 3
1400	0.8	1.1	0.9	0.55	-0.55	tributary 4
325	0.7	1.65	0.9	0.55	-1.10	tributary 4
230	0.9	0.55	0.9	0.55	0.00	tributary 4
290	0.7	1.65	0.9	0.55	-1.10	
2300	0.8	1.1	0.9	0.55	-0.55	
80	0.5	2.75	0.9	0.55	-2.20	
370	0.8	1.1	0.9	0.55	-0.55	
560	0.5	2.75	0.8	1.10	-1.65	
460	0.8	1.1	0.8	1.10	0.00	

Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
230	230	380	1	127	-253
285	285	627	1	157	-470
250	250	688	1	138	-550
120	360	594	3	198	-396
1150	3450	9488	3	1898	-7590
245	735	809	3	404	-404
500	500	825	1	275	-550
560	560	616	1	308	-308
145	435	718	3	239	-479
50	150	413	3	83	-330
365	365	602	1	201	-402
650	650	715	1	358	-358
940	2820	4653	3	1551	-3102
50	150	578	3	83	-495
1400	1400	1540	1	770	-770
325	975	1609	3	536	-1073

230	690	380	3	380	0	
290	290	479	1	160	-319	
2300	6900	7590	3	3795	-3795	
80	320	880	4	176	-704	
370	1480	1628	4	814	-814	
560	3920	10780	7	4312	-6468	
460	3220	3542	7	3542	0	
Total	**30135**	**50130**		**20501**	**-29629**	**-59**
						% Reduction

Table 27. Existing and Potential Solar Loads for Derr Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
790	0.8	1.1	0.9	0.55	-0.55	forest
930	0.9	0.55	0.9	0.55	0.00	
1160	0.8	1.1	0.9	0.55	-0.55	
2140	0.9	0.55	0.8	1.10	0.55	
950	0.8	1.1	0.8	1.10	0.00	
1080	0.1	4.95	0.7	1.65	-3.30	forest/shrub
460	0.2	4.4	0.7	1.65	-2.75	
580	0.1	4.95	0.7	1.65	-3.30	
60	0.2	4.4	0.7	1.65	-2.75	
75	0.1	4.95	0.7	1.65	-3.30	
150	0.3	3.85	0.7	1.65	-2.20	
400	0.2	4.4	0.7	1.65	-2.75	
565	0.1	4.95	0.7	1.65	-3.30	
145	0.2	4.4	0.7	1.65	-2.75	
150	0.1	4.95	0.7	1.65	-3.30	
2130	0	5.5	0.2	4.40	-1.10	backwater
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
790	790	869	1	435	-435	
930	2790	1535	3	1535	0	
1160	4640	5104	4	2552	-2552	
2140	10700	5885	5	11770	5885	
950	4750	5225	5	5225	0	
1080	7560	37422	7	12474	-24948	
460	3220	14168	7	5313	-8855	
580	4060	20097	7	6699	-13398	
60	420	1848	7	693	-1155	
75	525	2599	7	866	-1733	
150	1200	4620	8	1980	-2640	
400	3200	14080	8	5280	-8800	
565	4520	22374	8	7458	-14916	
145	1160	5104	8	1914	-3190	
150	1200	5940	8	1980	-3960	
2130	85200	468600	40	374880	-93720	
Total	**135935**	**615469**		**441053**	**-174416**	**-28**
						% Reduction

Table 28. Existing and Potential Solar Loads for Twin Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
1640	0.9	0.55	0.9	0.55	0.00	tributary 1
1000	0.8	1.1	0.9	0.55	-0.55	Delyle Cr.
1220	0.9	0.55	0.9	0.55	0.00	Delyle Cr.
1965	0.8	1.1	0.9	0.55	-0.55	Delyle Cr.
800	0.7	1.65	0.9	0.55	-1.10	Delyle Cr.
915	0.9	0.55	0.9	0.55	0.00	tributary 3
475	0.8	1.1	0.9	0.55	-0.55	tributary 3
2630	0.9	0.55	0.9	0.55	0.00	tributary 3
490	0.6	2.2	0.9	0.55	-1.65	tributary 3
695	0.9	0.55	0.9	0.55	0.00	tributary 3
290	0.7	1.65	0.9	0.55	-1.10	tributary 3
620	0.9	0.55	0.9	0.55	0.00	tributary 3
380	0.8	1.1	0.9	0.55	-0.55	tributary 3
230	0.8	1.1	0.9	0.55	-0.55	tributary 4
420	0.9	0.55	0.9	0.55	0.00	tributary 4
360	0.8	1.1	0.9	0.55	-0.55	tributary 4
270	0.9	0.55	0.9	0.55	0.00	tributary 4
250	0.7	1.65	0.9	0.55	-1.10	tributary 4
360	0.8	1.1	0.9	0.55	-0.55	tributary 4
500	0.5	2.75	0.9	0.55	-2.20	
510	0.7	1.65	0.9	0.55	-1.10	
490	0.8	1.1	0.9	0.55	-0.55	
3140	0.9	0.55	0.8	1.10	0.55	
870	0.7	1.65	0.8	1.10	-0.55	
310	0.8	1.1	0.8	1.10	0.00	
1230	0.7	1.65	0.8	1.10	-0.55	
145	0.8	1.1	0.7	1.65	0.55	
380	0.7	1.65	0.7	1.65	0.00	
1050	0.8	1.1	0.7	1.65	0.55	pathfinder = 86.9%
2270	0	5.5	0.6	2.20	-3.30	forest/shrub

Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)
1640	4920	2706	3	2706	0
1000	1000	1100	1	550	-550
1220	3660	2013	3	2013	0
1965	7860	8646	4	4323	-4323
800	3200	5280	4	1760	-3520
915	915	503	1	503	0
475	1425	1568	3	784	-784
2630	10520	5786	4	5786	0
490	1960	4312	4	1078	-3234

695	695	382	1	382	0	
290	290	479	1	160	-319	
620	1860	1023	3	1023	0	
380	1140	1254	3	627	-627	
230	230	253	1	127	-127	
420	420	231	1	231	0	
360	360	396	1	198	-198	
270	810	446	3	446	0	
250	750	1238	3	413	-825	
360	1080	1188	3	594	-594	
500	500	1375	1	275	-1100	
510	1530	2525	3	842	-1683	
490	1960	2156	4	1078	-1078	
3140	15700	8635	5	17270	8635	
870	6090	10049	7	6699	-3350	
310	2480	2728	8	2728	0	
1230	11070	18266	9	12177	-6089	
145	1595	1755	11	2632	877	
380	4180	6897	11	6897	0	
1050	11550	12705	11	19058	6353	
2270	24970	137335	11	54934	-82401	
Total	**124720**	**243227**		**148291**	**-94936**	**-39**
						% Reduction

Table 29. Existing and Potential Solar Loads for Dry Creek.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m^2/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m^2/day)	Potential Load minus Existing load (kWh/m^2/day)	
680	0.8	1.1	0.9	0.55	-0.55	tributary
230	0.7	1.65	0.9	0.55	-1.10	tributary
220	0.8	1.1	0.9	0.55	-0.55	tributary
550	0.7	1.65	0.9	0.55	-1.10	tributary
790	0.9	0.55	0.9	0.55	0.00	
4060	0.8	1.1	0.9	0.55	-0.55	
1025	0.7	1.65	0.8	1.10	-0.55	
1790	0.8	1.1	0.8	1.10	0.00	
70	0.6	2.2	0.8	1.10	-1.10	
930	0.8	1.1	0.8	1.10	0.00	
700	0.7	1.65	0.8	1.10	-0.55	
650	0.8	1.1	0.8	1.10	0.00	
600	0.7	1.65	0.8	1.10	-0.55	
Segment Length (meters)	Segment Area (m^2)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
680	680	748	1	374	-374	
230	690	1139	3	380	-759	
220	880	968	4	484	-484	
550	2750	4538	5	1513	-3025	
790	790	435	1	435	0	
4060	16240	17864	4	8932	-8932	
1025	5125	8456	5	5638	-2819	
1790	12530	13783	7	13783	0	
70	560	1232	8	616	-616	
930	7440	8184	8	8184	0	
700	5600	9240	8	6160	-3080	
650	5200	5720	8	5720	0	
600	4800	7920	8	5280	-2640	
Total	**63285**	**80226**		**57497**	**-22729**	**-28 % Reduction**

Table 30. Existing and Potential Solar Loads for Unnamed Tributary to Clark Fork River.

Segment Length (~meters)	Existing Shade (fraction)	Existing Summer Load (kWh/m²/day)	Target or Potential Shade (fraction)	Potential Summer Load (kWh/m²/day)	Potential Load minus Existing load (kWh/m²/day)	
780	0.8	1.1	0.9	0.55	-0.55	
910	0.9	0.55	0.9	0.55	0.00	
480	0.8	1.1	0.9	0.55	-0.55	
275	0.6	2.2	0.9	0.55	-1.65	
450	0.7	1.65	0.9	0.55	-1.10	
100	0	5.5	0.9	0.55	-4.95	
230	0.6	2.2	0.9	0.55	-1.65	
50	0	5.5	0.8	1.10	-4.40	
450	0.5	2.75	0.8	1.10	-1.65	
260	0.1	4.95	0.7	1.65	-3.30	forest/shrub
220	0.7	1.65	0.7	1.65	0.00	
80	0.6	2.2	0.7	1.65	-0.55	
390	0.8	1.1	0.7	1.65	0.55	
300	0.7	1.65	0.7	1.65	0.00	
130	0.9	0.55	0.7	1.65	1.10	
Segment Length (meters)	Segment Area (m²)	Existing Summer Load (kWh/day)	Natural Stream Width (m)	Potential Summer Load (kWh/day)	Potential Load minus Existing Load (kWh/day)	
780	780	858	1	429	-429	
910	910	501	1	501	0	
480	1440	1584	3	792	-792	
275	825	1815	3	454	-1361	
450	1800	2970	4	990	-1980	
100	400	2200	4	220	-1980	
230	920	2024	4	506	-1518	
50	250	1375	5	275	-1100	
450	2250	6188	5	2475	-3713	
260	1820	9009	7	3003	-6006	
220	1540	2541	7	2541	0	
80	560	1232	7	924	-308	
390	2730	3003	7	4505	1502	
300	2100	3465	7	3465	0	
130	910	501	7	1502	1001	
Total	**19235**	**39265**		**22580**	**-16684**	**-42**
						% Reduction

Figure 3. Existing Shade Estimated for the Lower Clark Fork Subbasin by Aerial Photo Interpretation.

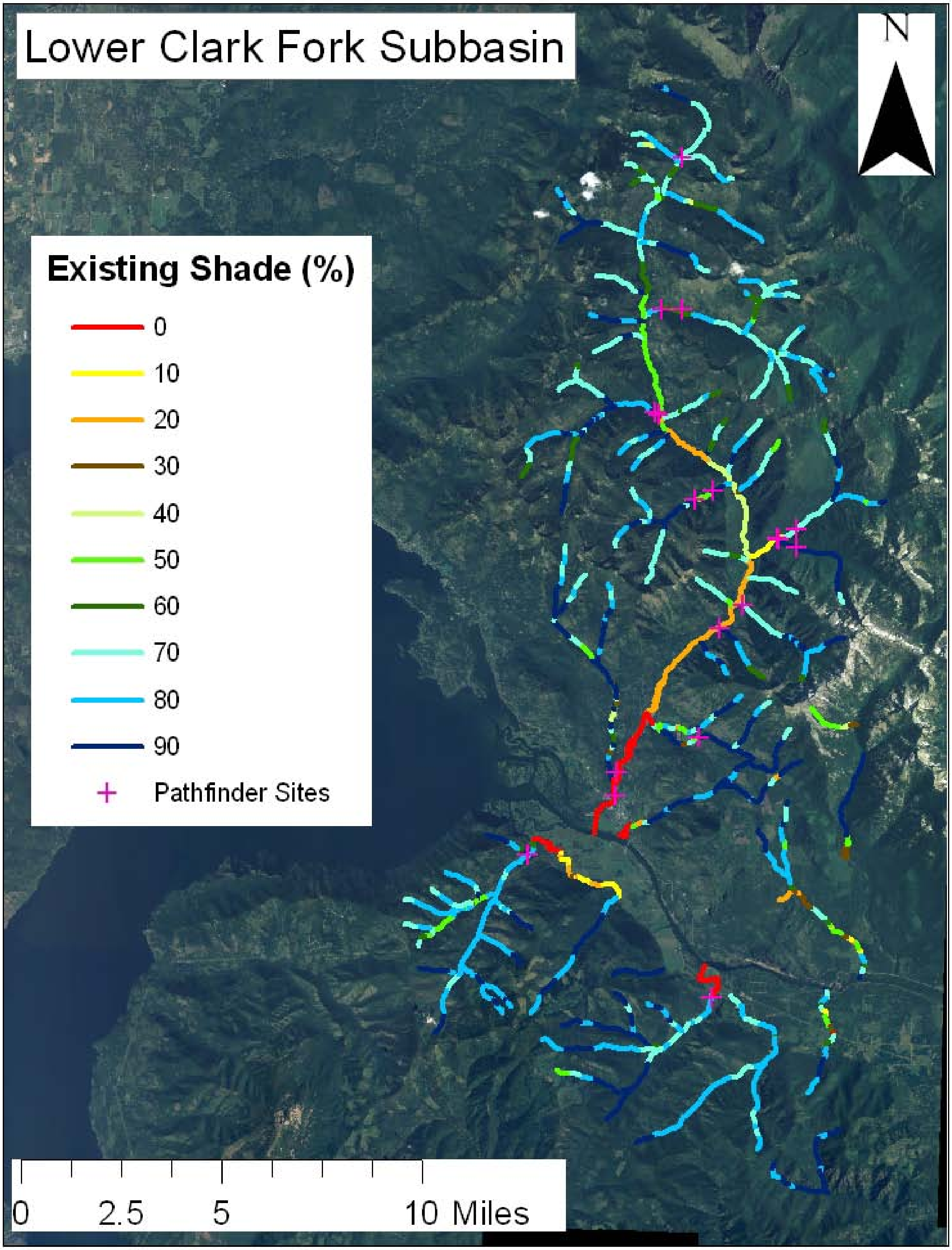
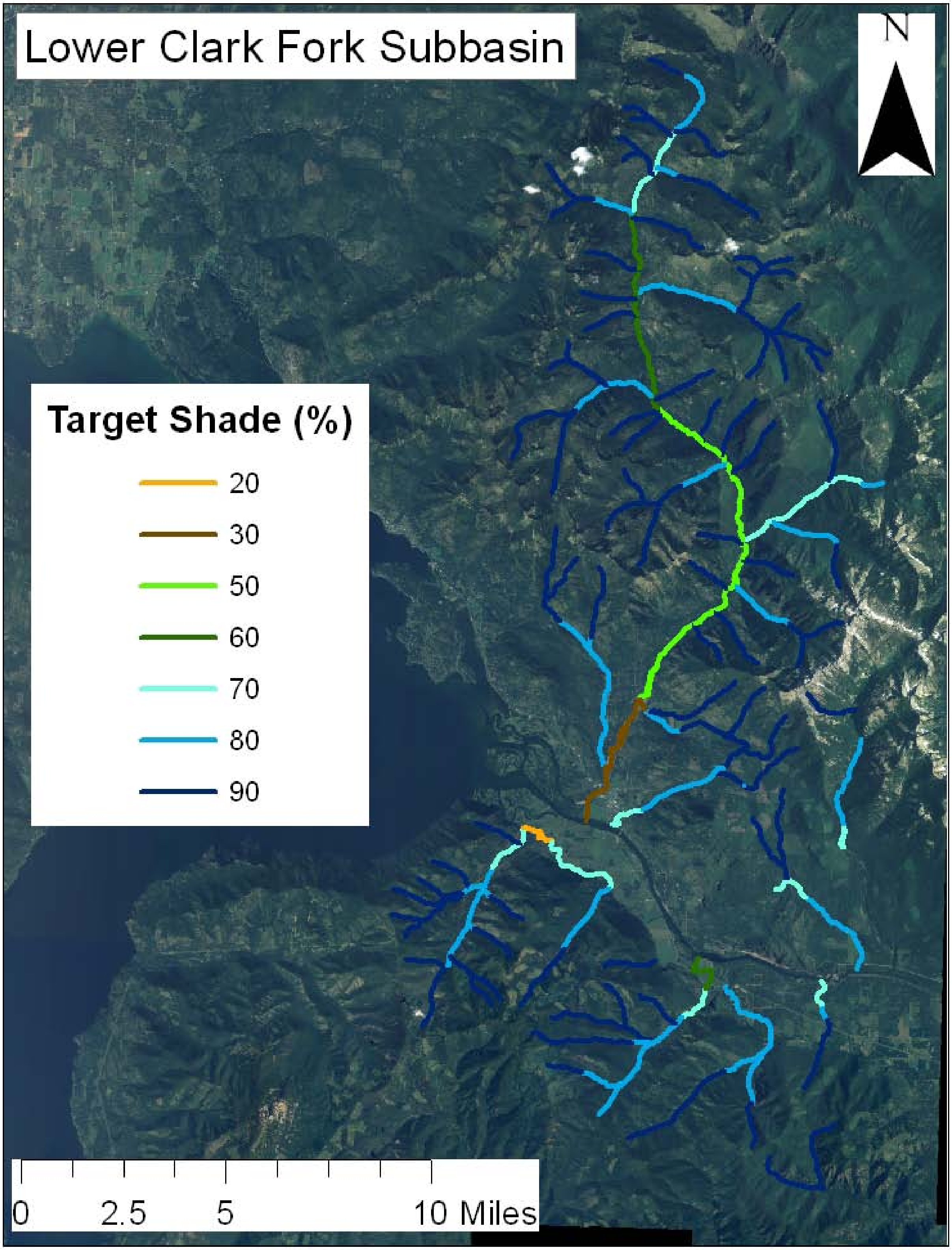


Figure 4. Target Shade (%) for the Lower Clark Fork Subbasin.



5.4b Load Allocation Temperature

Because this TMDL is based on potential natural vegetation, which is equivalent to background loading, the load allocation is essentially the desire to achieve background conditions. However, in order to reach that objective, load allocations are assigned to non point source activities that have or may affect riparian vegetation and shade. Load allocations are therefore stream reach specific and are dependent upon the target load for a given reach. Tables 4 through 30 show the target or potential shade which is converted to a potential summer load by multiplying the inverse fraction (1-shade fraction) by the average loading to a flat plate collector for the months of April through September. That is the loading capacity of the stream and it is necessary to achieve background conditions. There is no opportunity to allocate shade removal to an activity.

All streams examined had excess solar loads and require reductions to achieve loading capacity (Tables 31 and 32). Because all streams vary in size, their percent reduction does not necessarily reflect the amount of excess solar load received by the water body. The excess load for the Lower Clark Fork River is the sum of all tributary excess loads or more than 1.9 million kWh/day (Table 31). The sum of all tributary excess loads is 31% of the sum of all tributary existing loads. The excess load to Lightning Creek is the largest of the tributaries at 1.1 million kWh/day, however, its percent reduction is only 29% (Table 32). Conversely, the small headwaters tributaries (Gem, Gordon, Lunch Creeks) to Lightning Creek have some of the smallest excess loads yet their percent reductions are some of the highest at 60 to 70%.

Table 31. Excess Solar Load and Percent Reduction to Achieve Loading Capacity for the Lower Clark Fork River and Associated Tributaries.

Water Body	Excess Load (kWh/day)	Percent Reduction
Lower Clark Fork River	1,911,998	31%
Derr Creek	174,416	28%
Twin Creek	94,936	39%
Gold Creek	60,657	55%
Mosquito Creek	39,548	39%
West Johnson Creek	29,629	59%
Dry Creek	22,729	28%
Unnamed Tributary	16,684	42%
WF Blue Creek (ID only)	13,200	18%
Johnson Creek	8,294	8%

Lightning Creek has excess solar loads that are more than half (58%) of the total load experienced by the Clark Fork River, whose excess load is a summation of all tributary loads. Other streams with substantial excess loads include Derr Creek, Twin Creek, East Fork Creek, Gold Creek, and Rattle Creek.

Table 32. Excess Solar Load and Percent Reduction to Achieve Loading Capacity for Lightning Creek and Associated Tributaries.

Water Body	Excess Load (kWh/day)	Percent Reduction
Lightning Creek	1,113,682	29%
East Fork drainage	76,772	32%
Rattle Creek	55,743	49%
Mud, Steep, Silvertip, Trapper, etc.	30,649	62%
Spring Creek	30,635	30%
Cascade Creek	28,438	50%
Unnamed tributary	20,152	69%
Fall, Sheep & Bear Creeks	13,970	54%
Moose Creek	12,730	54%
Wellington Creek	12,683	20%
Morris Creek	11,729	32%
Porcupine Creek	9,807	19%
Gordon Creek	8,602	62%
Lunch Creek	7,158	73%
Gem Creek	5,830	66%
Quartz Creek	5,352	27%
Regal Creek	4,183	40%
Deer Creek	3,790	42%

It is assumed that if shade targets listed in Tables 4 through 30 are achieved on these water bodies, then excess loads will be reduced to zero and streams will be at background solar loads as expected under potential natural vegetation conditions. Nonpoint source activities in the subbasin are allocated the percent reductions specified in Tables 31 and 32 by water body, not by activity. Thus, each watershed needs to be examined for whatever activities influence riparian conditions and shade in particular.

This temperature loading analysis assumes there are no point sources in the affected watersheds. Thus, there are no wasteload allocations either. Wasteload allocations for any existing or future point source discharge should be developed based on mass balance approach. Thus, the permitted temperature of the discharge will depend on the volume of water discharged, the volume of the receiving water and applicable water quality standards. Should a point source be proposed after shade targets are achieved that would have thermal consequence on these waters, then background provisions addressing such discharges in Idaho water quality standards (IDAPA 58.01.02.200.09 & IDAPA 58.01.02.401.03) should be involved (see Appendix B).

Margin of Safety

The margin of safety in this temperature TMDL is considered implicit in the design. Because the target is essentially background conditions, there are no loads allocated to sources or activities. Although the loading analysis used in this TMDL involves gross estimations that are likely to have large variances, there are no load allocations that may benefit or suffer from that variance.

Seasonal Variation

This temperature TMDL is based on average summer loads. All loads have been calculated to be inclusive of the six month period from April through September. This time period was chosen because it represents the time period when the combination of increasing air and water temperatures coincides with increasing solar inputs and increasing vegetative shade. The critical time period is June when spring salmonids spawning is occurring, July and August when maximum temperatures exceed cold water aquatic life criteria, and September during fall salmonids spawning. Water temperature is not likely to be a problem for beneficial uses outside of this time period because of cooler weather and lower sun angle.

Construction Storm Water and TMDL Waste Load Allocations

Construction Storm Water

The Clean Water Act requires operators of construction sites to obtain permit coverage to discharge storm water to a water body or to a municipal storm sewer. In Idaho, EPA has issued a general permit for storm water discharges from construction sites. In the past storm water was treated as a non-point source of pollutants. However, because storm water can be managed on site through management practices or when discharged through a discrete conveyance such as a storm sewer, it now requires a National Pollution Discharge Elimination System (NPDES) Permit.

The Construction General Permit (CGP)

If a construction project disturbs more than one acre of land (or is part of larger common development) that will disturb more than one acre, the operator is required to apply for permit coverage from EPA after developing a site-specific Storm Water Pollution Prevention Plan.

Storm Water Pollution Prevention Plan (SWPPP)

In order to obtain the Construction General Permit operators must develop a site-specific Storm Water Pollution Prevention Plan. The operator must document the erosion, sediment, and pollution controls they intend to use, inspect the controls periodically and maintain the best management practices (BMPs) through the life of the project

Construction Storm Water Requirements

When a stream is on Idaho's § 303(d) list and has a TMDL developed DEQ now incorporates a gross waste load allocation (WLA) for anticipated construction storm water activities. TMDLs developed in the past that did not have a WLA for construction storm water activities will also be considered in compliance with provisions of the TMDL if they obtain a CGP under the NPDES program and implement the appropriate Best Management Practices.

Typically there are specific requirements you must follow to be consistent with any local pollutant allocations. Many communities throughout Idaho are currently developing rules for post-construction storm water management. Sediment is usually the main pollutant of concern in storm water from construction sites. The application of specific best management practices from *Idaho's Catalog of Storm Water Best Management Practices for Idaho Cities and Counties* is generally sufficient to meet the standards and requirements of the General Construction Permit, unless local ordinances have more stringent and site specific standards that are applicable.

5.6 Conclusions

Table X. Summary of assessment outcomes. [to be updated when complete]

Water Body Segment/ AU	Pollutant	TMDL(s) Completed	Recommended Changes to §303(d) List	Justification
		Yes		
		Yes		

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GIS Coverages

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Add list of GIS coverages to end of references (see guidance).

Glossary

305(b)

Refers to section 305 subsection "b" of the Clean Water Act. The term "305(b)" generally describes a report of each state's water quality and is the principle means by which the U.S. Environmental Protection Agency, Congress, and the public evaluate whether U.S. waters meet water quality standards, the progress made in maintaining and restoring water quality, and the extent of the remaining problems.

§303(d)

Refers to section 303 subsection "d" of the Clean Water Act. 303(d) requires states to develop a list of water bodies that do not meet water quality standards. This section also requires total maximum daily loads (TMDLs) be prepared for listed waters. Both the list and the TMDLs are subject to U.S. Environmental Protection Agency approval.

Acre-foot

A volume of water that would cover an acre to a depth of one foot. Often used to quantify reservoir storage and the annual discharge of large rivers.

Adsorption

The adhesion of one substance to the surface of another. Clays, for example, can adsorb phosphorus and organic molecules

Aeration

A process by which water becomes charged with air directly from the atmosphere. Dissolved gases, such as oxygen, are then available for reactions in water.

Aerobic

Describes life, processes, or conditions that require the presence of oxygen.

Adfluvial

Describes fish whose life history involves seasonal migration from lakes to streams for spawning.

Adjunct

In the context of water quality, adjunct refers to areas directly adjacent to focal or refuge habitats that have been degraded by human or natural disturbances and do not presently support high diversity or abundance of native species.

Alevin	A newly hatched, incompletely developed fish (usually a salmonid) still in nest or inactive on the bottom of a water body, living off stored yolk.
Algae	Non-vascular (without water-conducting tissue) aquatic plants that occur as single cells, colonies, or filaments.
Alluvium	Unconsolidated recent stream deposition.
Ambient	General conditions in the environment (Armantrout 1998). In the context of water quality, ambient waters are those representative of general conditions, not associated with episodic perturbations or specific disturbances such as a wastewater outfall (EPA 1996).
Anadromous	Fish, such as salmon and sea-run trout, that live part or the majority of their lives in the saltwater but return to fresh water to spawn.
Anaerobic	Describes the processes that occur in the absence of molecular oxygen and describes the condition of water that is devoid of molecular oxygen.
Anoxia	The condition of oxygen absence or deficiency.
Anthropogenic	Relating to, or resulting from, the influence of human beings on nature.
Anti-Degradation	Refers to the U.S. Environmental Protection Agency's interpretation of the Clean Water Act goal that states and tribes maintain, as well as restore, water quality. This applies to waters that meet or are of higher water quality than required by state standards. State rules provide that the quality of those high quality waters may be lowered only to allow important social or economic development and only after adequate public participation (IDAPA 58.01.02.051). In all cases, the existing beneficial uses must be maintained. State rules further define lowered water quality to be 1) a measurable change, 2) a change adverse to a use, and 3) a change in a pollutant relevant to the water's uses (IDAPA 58.01.02.003.61).

Aquatic	Occurring, growing, or living in water.
Aquifer	An underground, water-bearing layer or stratum of permeable rock, sand, or gravel capable of yielding of water to wells or springs.
Assemblage (aquatic)	An association of interacting populations of organisms in a given water body; for example, a fish assemblage or a benthic macroinvertebrate assemblage (also see Community) (EPA 1996).
Assessment Database (ADB)	The ADB is a relational database application designed for the U.S. Environmental Protection Agency for tracking water quality assessment data, such as use attainment and causes and sources of impairment. States need to track this information and many other types of assessment data for thousands of water bodies and integrate it into meaningful reports. The ADB is designed to make this process accurate, straightforward, and user-friendly for participating states, territories, tribes, and basin commissions.
Assessment Unit (AU)	A segment of a water body that is treated as a homogenous unit, meaning that any designated uses, the rating of these uses, and any associated causes and sources must be applied to the entirety of the unit.
Assimilative Capacity	The ability to process or dissipate pollutants without ill effect to beneficial uses.
Autotrophic	An organism is considered autotrophic if it uses carbon dioxide as its main source of carbon. This most commonly happens through photosynthesis.
Batholith	A large body of intrusive igneous rock that has more than 40 square miles of surface exposure and no known floor. A batholith usually consists of coarse-grained rocks such as granite.
Bedload	Material (generally sand-sized or larger sediment) that is carried along the streambed by rolling or bouncing.

Beneficial Use

Any of the various uses of water, including, but not limited to, aquatic life, recreation, water supply, wildlife habitat, and aesthetics, which are recognized in water quality standards.

Beneficial Use Reconnaissance Program (BURP)

A program for conducting systematic biological and physical habitat surveys of water bodies in Idaho. BURP protocols address lakes, reservoirs, and wadeable streams and rivers

Benthic

Pertaining to or living on or in the bottom sediments of a water body

Benthic Organic Matter.

The organic matter on the bottom of a water body.

Benthos

Organisms living in and on the bottom sediments of lakes and streams. Originally, the term meant the lake bottom, but it is now applied almost uniformly to the animals associated with the lake and stream bottoms.

Best Management Practices (BMPs)

Structural, nonstructural, and managerial techniques that are effective and practical means to control nonpoint source pollutants.

Best Professional Judgment

A conclusion and/or interpretation derived by a trained and/or technically competent individual by applying interpretation and synthesizing information.

Biochemical Oxygen Demand (BOD)

The amount of dissolved oxygen used by organisms during the decomposition (respiration) of organic matter, expressed as mass of oxygen per volume of water, over some specified period of time.

Biological Integrity

1) The condition of an aquatic community inhabiting unimpaired water bodies of a specified habitat as measured by an evaluation of multiple attributes of the aquatic biota (EPA 1996). 2) The ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to the natural habitats of a region (Karr 1991).

Biomass	The weight of biological matter. Standing crop is the amount of biomass (e.g., fish or algae) in a body of water at a given time. Often expressed as grams per square meter.
Biota	The animal and plant life of a given region.
Biotic	A term applied to the living components of an area.
Clean Water Act (CWA)	The Federal Water Pollution Control Act (commonly known as the Clean Water Act), as last reauthorized by the Water Quality Act of 1987, establishes a process for states to use to develop information on, and control the quality of, the nation's water resources.
Coliform Bacteria	A group of bacteria predominantly inhabiting the intestines of humans and animals but also found in soil. Coliform bacteria are commonly used as indicators of the possible presence of pathogenic organisms (also see Fecal Coliform Bacteria, *E. Coli*, and Pathogens).
Colluvium	Material transported to a site by gravity.
Community	A group of interacting organisms living together in a given place.
Conductivity	The ability of an aqueous solution to carry electric current, expressed in micro (μ) mhos/centimeter at 25 °C. Conductivity is affected by dissolved solids and is used as an indirect measure of total dissolved solids in a water sample.
Cretaceous	The final period of the Mesozoic era (after the Jurassic and before the Tertiary period of the Cenozoic era), thought to have covered the span of time between 135 and 65 million years ago.
Criteria	In the context of water quality, numeric or descriptive factors taken into account in setting standards for various pollutants. These factors are used to determine limits on allowable concentration levels, and to limit the number of violations per year. The U.S. Environmental Protection Agency develops criteria guidance; states establish criteria.

Cubic Feet per Second

A unit of measure for the rate of flow or discharge of water. One cubic foot per second is the rate of flow of a stream with a cross-section of one square foot flowing at a mean velocity of one foot per second. At a steady rate, once cubic foot per second is equal to 448.8 gallons per minute and 10,984 acre-feet per day.

Cultural Eutrophication

The process of eutrophication that has been accelerated by human-caused influences. Usually seen as an increase in nutrient loading (also see Eutrophication).

Culturally Induced Erosion

Erosion caused by increased runoff or wind action due to the work of humans in deforestation, cultivation of the land, overgrazing, and disturbance of natural drainages; the excess of erosion over the normal for an area (also see Erosion).

Debris Torrent

The sudden down slope movement of soil, rock, and vegetation on steep slopes, often caused by saturation from heavy rains.

Decomposition

The breakdown of organic molecules (e.g., sugar) to inorganic molecules (e.g., carbon dioxide and water) through biological and nonbiological processes.

Depth Fines

Percent by weight of particles of small size within a vertical core of volume of a streambed or lake bottom sediment. The upper size threshold for fine sediment for fisheries purposes varies from 0.8 to 6.5 millimeters depending on the observer and methodology used. The depth sampled varies but is typically about one foot (30 centimeters).

Designated Uses

Those water uses identified in state water quality standards that must be achieved and maintained as required under the Clean Water Act.

Discharge

The amount of water flowing in the stream channel at the time of measurement. Usually expressed as cubic feet per second (cfs).

Dissolved Oxygen (DO)

The oxygen dissolved in water. Adequate DO is vital to fish and other aquatic life.

Disturbance	Any event or series of events that disrupts ecosystem, community, or population structure and alters the physical environment.
E. coli	Short for *Escherichia coli*, *E. coli* are a group of bacteria that are a subspecies of coliform bacteria. Most *E. coli* are essential to the healthy life of all warm-blooded animals, including humans, but their presence in water is often indicative of fecal contamination. *E. coli* are used by the state of Idaho as the indicator for the presence of pathogenic microorganisms.
Ecology	The scientific study of relationships between organisms and their environment; also defined as the study of the structure and function of nature.
Ecological Indicator	A characteristic of an ecosystem that is related to, or derived from, a measure of a biotic or abiotic variable that can provide quantitative information on ecological structure and function. An indicator can contribute to a measure of integrity and sustainability. Ecological indicators are often used within the multimetric index framework.
Ecological Integrity	The condition of an unimpaired ecosystem as measured by combined chemical, physical (including habitat), and biological attributes (EPA 1996).
Ecosystem	The interacting system of a biological community and its non-living (abiotic) environmental surroundings.
Effluent	A discharge of untreated, partially treated, or treated wastewater into a receiving water body.
Endangered Species	Animals, birds, fish, plants, or other living organisms threatened with imminent extinction. Requirements for declaring a species as endangered are contained in the Endangered Species Act.
Environment	The complete range of external conditions, physical and biological, that affect a particular organism or community.

Eocene

An epoch of the early Tertiary period, after the Paleocene and before the Oligocene.

Eolian

Windblown, referring to the process of erosion, transport, and deposition of material by the wind.

Ephemeral Stream

A stream or portion of a stream that flows only in direct response to precipitation. It receives little or no water from springs and no long continued supply from melting snow or other sources. Its channel is at all times above the water table (American Geological Institute 1962).

Erosion

The wearing away of areas of the earth's surface by water, wind, ice, and other forces.

Eutrophic

From Greek for "well nourished," this describes a highly productive body of water in which nutrients do not limit algal growth. It is typified by high algal densities and low clarity.

Eutrophication

1) Natural process of maturing (aging) in a body of water. 2) The natural and human-influenced process of enrichment with nutrients, especially nitrogen and phosphorus, leading to an increased production of organic matter.

Exceedance

A violation (according to DEQ policy) of the pollutant levels permitted by water quality criteria.

Existing Beneficial Use or Existing Use

A beneficial use actually attained in waters on or after November 28, 1975, whether or not the use is designated for the waters in Idaho's *Water Quality Standards and Wastewater Treatment Requirements* (IDAPA 58.01.02).

Exotic Species

A species that is not native (indigenous) to a region.

Extrapolation

Estimation of unknown values by extending or projecting from known values.

Fauna

Animal life, especially the animals characteristic of a region, period, or special environment.

Fecal Coliform Bacteria

Bacteria found in the intestinal tracts of all warm-blooded animals or mammals. Their presence in water is an indicator of pollution and possible contamination by pathogens (also see Coliform Bacteria, *E. coli*, and Pathogens).

Fecal Streptococci

A species of spherical bacteria including pathogenic strains found in the intestines of warm-blooded animals.

Feedback Loop

In the context of watershed management planning, a feedback loop is a process that provides for tracking progress toward goals and revising actions according to that progress.

Fixed-Location Monitoring

Sampling or measuring environmental conditions continuously or repeatedly at the same location.

Flow

See *Discharge*.

Fluvial

In fisheries, this describes fish whose life history takes place entirely in streams but migrate to smaller streams for spawning.

Focal

Critical areas supporting a mosaic of high quality habitats that sustain a diverse or unusually productive complement of native species.

Fully Supporting

In compliance with water quality standards and within the range of biological reference conditions for all designated and exiting beneficial uses as determined through the *Water Body Assessment Guidance* (Grafe et al. 2002).

Fully Supporting Cold Water

Reliable data indicate functioning, sustainable cold water biological assemblages (e.g., fish, macroinvertebrates, or algae), none of which have been modified significantly beyond the natural range of reference conditions.

Fully Supporting but Threatened

An intermediate assessment category describing water bodies that fully support beneficial uses, but have a declining trend in water quality conditions, which if not addressed, will lead to a "not fully supporting" status.

Geographical Information Systems (GIS)

A georeferenced database.

Geometric Mean	A back-transformed mean of the logarithmically transformed numbers often used to describe highly variable, right-skewed data (a few large values), such as bacterial data.
Grab Sample	A single sample collected at a particular time and place. It may represent the composition of the water in that water column.
Gradient	The slope of the land, water, or streambed surface.
Ground Water	Water found beneath the soil surface saturating the layer in which it is located. Most ground water originates as rainfall, is free to move under the influence of gravity, and usually emerges again as stream flow.
Growth Rate	A measure of how quickly something living will develop and grow, such as the amount of new plant or animal tissue produced per a given unit of time, or number of individuals added to a population.
Habitat	The living place of an organism or community.
Headwater	The origin or beginning of a stream.
Hydrologic Basin	The area of land drained by a river system, a reach of a river and its tributaries in that reach, a closed basin, or a group of streams forming a drainage area (also see Watershed).
Hydrologic Cycle	The cycling of water from the atmosphere to the earth (precipitation) and back to the atmosphere (evaporation and plant transpiration). Atmospheric moisture, clouds, rainfall, runoff, surface water, ground water, and water infiltrated in soils are all part of the hydrologic cycle.
Hydrologic Unit	One of a nested series of numbered and named watersheds arising from a national standardization of watershed delineation. The initial 1974 effort (USGS 1987) described four levels (region, subregion, accounting unit, cataloging unit) of watersheds throughout the United States. The fourth level is uniquely identified by an eight-digit code built of two-digit fields for each level in the classification. Originally termed a cataloging unit, fourth field hydrologic units have been more

commonly called subbasins. Fifth and sixth field hydrologic units have since been delineated for much of the country and are known as watershed and subwatersheds, respectively.

Hydrologic Unit Code (HUC)

The number assigned to a hydrologic unit. Often used to refer to fourth field hydrologic units.

Hydrology

The science dealing with the properties, distribution, and circulation of water.

Impervious

Describes a surface, such as pavement, that water cannot penetrate.

Influent

A tributary stream.

Inorganic

Materials not derived from biological sources.

Instantaneous

A condition or measurement at a moment (instant) in time.

Intergravel Dissolved Oxygen

The concentration of dissolved oxygen within spawning gravel. Consideration for determining spawning gravel includes species, water depth, velocity, and substrate.

Intermittent Stream

1) A stream that flows only part of the year, such as when the ground water table is high or when the stream receives water from springs or from surface sources such as melting snow in mountainous areas. The stream ceases to flow above the streambed when losses from evaporation or seepage exceed the available stream flow. 2) A stream that has a period of zero flow for at least one week during most years.

Interstate Waters

Waters that flow across or form part of state or international boundaries, including boundaries with Native American nations.

Irrigation Return Flow

Surface (and subsurface) water that leaves a field following the application of irrigation water and eventually flows into streams.

Key Watershed

A watershed that has been designated in Idaho Governor Batt's *State of Idaho Bull Trout Conservation Plan* (1996) as critical to the long-term persistence of regionally important trout populations.

Knickpoint	Any interruption or break of slope.
Land Application	A process or activity involving application of wastewater, surface water, or semi-liquid material to the land surface for the purpose of treatment, pollutant removal, or ground water recharge.
Limiting Factor	A chemical or physical condition that determines the growth potential of an organism. This can result in a complete inhibition of growth, but typically results in less than maximum growth rates.
Limnology	The scientific study of fresh water, especially the history, geology, biology, physics, and chemistry of lakes.
Load Allocation (LA)	A portion of a water body's load capacity for a given pollutant that is given to a particular nonpoint source (by class, type, or geographic area).
Load(ing)	The quantity of a substance entering a receiving stream, usually expressed in pounds or kilograms per day or tons per year. Loading is the product of flow (discharge) and concentration.
Load(ing) Capacity (LC)	A determination of how much pollutant a water body can receive over a given period without causing violations of state water quality standards. Upon allocation to various sources, and a margin of safety, it becomes a total maximum daily load.
Loam	Refers to a soil with a texture resulting from a relative balance of sand, silt, and clay. This balance imparts many desirable characteristics for agricultural use.
Loess	A uniform wind-blown deposit of silty material. Silty soils are among the most highly erodible.
Lotic	An aquatic system with flowing water such as a brook, stream, or river where the net flow of water is from the headwaters to the mouth.

Luxury Consumption	A phenomenon in which sufficient nutrients are available in either the sediments or the water column of a water body, such that aquatic plants take up and store an abundance in excess of the plants' current needs.
Macroinvertebrate	An invertebrate animal (without a backbone) large enough to be seen without magnification and retained by a 500µm mesh (U.S. #30) screen.
Macrophytes	Rooted and floating vascular aquatic plants, commonly referred to as water weeds. These plants usually flower and bear seeds. Some forms, such as duckweed and coontail (*Ceratophyllum sp.*), are free-floating forms not rooted in sediment.
Margin of Safety (MOS)	An implicit or explicit portion of a water body's loading capacity set aside to allow the uncertainly about the relationship between the pollutant loads and the quality of the receiving water body. This is a required component of a total maximum daily load (TMDL) and is often incorporated into conservative assumptions used to develop the TMDL (generally within the calculations and/or models). The MOS is not allocated to any sources of pollution.
Mass Wasting	A general term for the down slope movement of soil and rock material under the direct influence of gravity.
Mean	Describes the central tendency of a set of numbers. The arithmetic mean (calculated by adding all items in a list, then dividing by the number of items) is the statistic most familiar to most people.
Median	The middle number in a sequence of numbers. If there are an even number of numbers, the median is the average of the two middle numbers. For example, 4 is the median of 1, 2, 4, 14, 16; 6 is the median of 1, 2, 5, 7, 9, 11.
Metric	1) A discrete measure of something, such as an ecological indicator (e.g., number of distinct taxon). 2) The metric system of measurement.

Milligrams per Liter (mg/L)

A unit of measure for concentration. In water, it is essentially equivalent to parts per million (ppm).

Million Gallons per Day (MGD)

A unit of measure for the rate of discharge of water, often used to measure flow at wastewater treatment plants. One MGD is equal to 1.547 cubic feet per second.

Miocene

Of, relating to, or being an epoch of, the Tertiary between the Pliocene and the Oligocene periods, or the corresponding system of rocks.

Monitoring

A periodic or continuous measurement of the properties or conditions of some medium of interest, such as monitoring a water body.

Mouth

The location where flowing water enters into a larger water body.

National Pollution Discharge Elimination System (NPDES)

A national program established by the Clean Water Act for permitting point sources of pollution. Discharge of pollution from point sources is not allowed without a permit.

Natural Condition

The condition that exists with little or no anthropogenic influence.

Nitrogen

An element essential to plant growth, and thus is considered a nutrient.

Nodal

Areas that are separated from focal and adjunct habitats, but serve critical life history functions for individual native fish.

Nonpoint Source

A dispersed source of pollutants, generated from a geographical area when pollutants are dissolved or suspended in runoff and then delivered into waters of the state. Nonpoint sources are without a discernable point or origin. They include, but are not limited to, irrigated and non-irrigated lands used for grazing, crop production, and silviculture; rural roads; construction and mining sites; log storage or rafting; and recreation sites.

Not Assessed (NA)

A concept and an assessment category describing water bodies that have been studied, but are missing critical information needed to complete an assessment.

Not Attainable

A concept and an assessment category describing water bodies that demonstrate characteristics that make it unlikely that a beneficial use can be attained (e.g., a stream that is dry but designated for salmonid spawning).

Not Fully Supporting

Not in compliance with water quality standards or not within the range of biological reference conditions for any beneficial use as determined through the *Water Body Assessment Guidance* (Grafe et al. 2002).

Not Fully Supporting Cold Water

At least one biological assemblage has been significantly modified beyond the natural range of its reference condition.

Nuisance

Anything that is injurious to the public health or an obstruction to the free use, in the customary manner, of any waters of the state.

Nutrient

Any substance required by living things to grow. An element or its chemical forms essential to life, such as carbon, oxygen, nitrogen, and phosphorus. Commonly refers to those elements in short supply, such as nitrogen and phosphorus, which usually limit growth.

Nutrient Cycling

The flow of nutrients from one component of an ecosystem to another, as when macrophytes die and release nutrients that become available to algae (organic to inorganic phase and return).

Oligotrophic

The Greek term for "poorly nourished." This describes a body of water in which productivity is low and nutrients are limiting to algal growth, as typified by low algal density and high clarity.

Organic Matter

Compounds manufactured by plants and animals that contain principally carbon.

Orthophosphate

A form of soluble inorganic phosphorus most readily used for algal growth.

Oxygen-Demanding Materials

Those materials, mainly organic matter, in a water body that consume oxygen during decomposition.

Parameter

A variable, measurable property whose value is a determinant of the characteristics of a system, such as temperature, dissolved oxygen, and fish populations are parameters of a stream or lake.

Partitioning

The sharing of limited resources by different races or species; use of different parts of the habitat, or the same habitat at different times. Also the separation of a chemical into two or more phases, such as partitioning of phosphorus between the water column and sediment.

Pathogens

A small subset of microorganisms (e.g., certain bacteria, viruses, and protozoa) that can cause sickness or death. Direct measurement of pathogen levels in surface water is difficult. Consequently, indicator bacteria that are often associated with pathogens are assessed. *E. coli*, a type of fecal coliform bacteria, are used by the state of Idaho as the indicator for the presence of pathogenic microorganisms.

Perennial Stream

A stream that flows year-around in most years.

Periphyton

Attached microflora (algae and diatoms) growing on the bottom of a water body or on submerged substrates, including larger plants.

Pesticide

Substances or mixtures of substances intended for preventing, destroying, repelling, or mitigating any pest. Also, any substance or mixture intended for use as a plant regulator, defoliant, or desiccant.

pH

The negative $\log_{10}$ of the concentration of hydrogen ions, a measure which in water ranges from very acid (pH=1) to very alkaline (pH=14). A pH of 7 is neutral. Surface waters usually measure between pH 6 and 9.

Phased TMDL	A total maximum daily load (TMDL) that identifies interim load allocations and details further monitoring to gauge the success of management actions in achieving load reduction goals and the effect of actual load reductions on the water quality of a water body. Under a phased TMDL, a refinement of load allocations, wasteload allocations, and the margin of safety is planned at the outset.
Phosphorus	An element essential to plant growth, often in limited supply, and thus considered a nutrient.
Physiochemical	In the context of bioassessment, the term is commonly used to mean the physical and chemical factors of the water column that relate to aquatic biota. Examples in bioassessment usage include saturation of dissolved gases, temperature, pH, conductivity, dissolved or suspended solids, forms of nitrogen, and phosphorus. This term is used interchangeable with the term “physical/chemical.”
Plankton	Microscopic algae (phytoplankton) and animals (zooplankton) that float freely in open water of lakes and oceans.
Point Source	A source of pollutants characterized by having a discrete conveyance, such as a pipe, ditch, or other identifiable “point” of discharge into a receiving water. Common point sources of pollution are industrial and municipal wastewater.
Pollutant	Generally, any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.
Pollution	A very broad concept that encompasses human-caused changes in the environment which alter the functioning of natural processes and produce undesirable environmental and health effects. This includes human-induced alteration of the physical, biological, chemical, and radiological integrity of water and other media.
Population	A group of interbreeding organisms occupying a particular space; the number of humans or other living creatures in a designated area.

Term	Definition
Pretreatment	The reduction in the amount of pollutants, elimination of certain pollutants, or alteration of the nature of pollutant properties in wastewater prior to, or in lieu of, discharging or otherwise introducing such wastewater into a publicly owned wastewater treatment plant.
Primary Productivity	The rate at which algae and macrophytes fix carbon dioxide using light energy. Commonly measured as milligrams of carbon per square meter per hour.
Protocol	A series of formal steps for conducting a test or survey.
Qualitative	Descriptive of kind, type, or direction.
Quality Assurance (QA)	A program organized and designed to provide accurate and precise results. Included are the selection of proper technical methods, tests, or laboratory procedures; sample collection and preservation; the selection of limits; data evaluation; quality control; and personnel qualifications and training (Rand 1995). The goal of QA is to assure the data provided are of the quality needed and claimed (EPA 1996).
Quality Control (QC)	Routine application of specific actions required to provide information for the quality assurance program. Included are standardization, calibration, and replicate samples (Rand 1995). QC is implemented at the field or bench level (EPA 1996).
Quantitative	Descriptive of size, magnitude, or degree.
Reach	A stream section with fairly homogenous physical characteristics.
Reconnaissance	An exploratory or preliminary survey of an area.
Reference	A physical or chemical quantity whose value is known and thus is used to calibrate or standardize instruments.
Reference Condition	1) A condition that fully supports applicable beneficial uses with little affect from human activity and represents the highest

level of support attainable. 2) A benchmark for populations of aquatic ecosystems used to describe desired conditions in a biological assessment and acceptable or unacceptable departures from them. The reference condition can be determined through examining regional reference sites, historical conditions, quantitative models, and expert judgment (Hughes 1995).

Reference Site

A specific locality on a water body that is minimally impaired and is representative of reference conditions for similar water bodies.

Representative Sample

A portion of material or water that is as similar in content and consistency as possible to that in the larger body of material or water being sampled.

Resident

A term that describes fish that do not migrate.

Respiration

A process by which organic matter is oxidized by organisms, including plants, animals, and bacteria. The process converts organic matter to energy, carbon dioxide, water, and lesser constituents.

Riffle

A relatively shallow, gravelly area of a streambed with a locally fast current, recognized by surface choppiness. Also an area of higher streambed gradient and roughness.

Riparian

Associated with aquatic (stream, river, lake) habitats. Living or located on the bank of a water body.

Riparian Habitat Conservation Area (RHCA)

A U.S. Forest Service description of land within the following number of feet up-slope of each of the banks of streams:

- 300 feet from perennial fish-bearing streams
- 150 feet from perennial non-fish-bearing streams
- 100 feet from intermittent streams, wetlands, and ponds in priority watersheds.

River

A large, natural, or human-modified stream that flows in a defined course or channel or in a series of diverging and converging channels.

Runoff	The portion of rainfall, melted snow, or irrigation water that flows across the surface, through shallow underground zones (interflow), and through ground water to creates streams.
Sediments	Deposits of fragmented materials from weathered rocks and organic material that were suspended in, transported by, and eventually deposited by water or air.
Settleable Solids	The volume of material that settles out of one liter of water in one hour.
Species	1) A reproductively isolated aggregate of interbreeding organisms having common attributes and usually designated by a common name. 2) An organism belonging to such a category.
Spring	Ground water seeping out of the earth where the water table intersects the ground surface.
Stagnation	The absence of mixing in a water body.
Stenothermal	Unable to tolerate a wide temperature range.
Stratification	A Department of Environmental Quality classification method used to characterize comparable units (also called classes or strata).
Stream	A natural water course containing flowing water, at least part of the year. Together with dissolved and suspended materials, a stream normally supports communities of plants and animals within the channel and the riparian vegetation zone.
Stream Order	Hierarchical ordering of streams based on the degree of branching. A first-order stream is an unforked or unbranched stream. Under Strahler's (1957) system, higher order streams result from the joining of two streams of the same order.
Storm Water Runoff	Rainfall that quickly runs off the land after a storm. In developed watersheds the water flows off roofs and pavement into storm drains that may feed quickly and directly into the

stream. The water often carries pollutants picked up from these surfaces.

Stressors

Physical, chemical, or biological entities that can induce adverse effects on ecosystems or human health.

Subbasin

A large watershed of several hundred thousand acres. This is the name commonly given to 4th field hydrologic units (also see Hydrologic Unit).

Subbasin Assessment (SBA)

A watershed-based problem assessment that is the first step in developing a total maximum daily load in Idaho.

Subwatershed

A smaller watershed area delineated within a larger watershed, often for purposes of describing and managing localized conditions. Also proposed for adoption as the formal name for 6th field hydrologic units.

Surface Fines

Sediments of small size deposited on the surface of a streambed or lake bottom. The upper size threshold for fine sediment for fisheries purposes varies from 0.8 to 605 millimeters depending on the observer and methodology used. Results are typically expressed as a percentage of observation points with fine sediment.

Surface Runoff

Precipitation, snow melt, or irrigation water in excess of what can infiltrate the soil surface and be stored in small surface depressions; a major transporter of nonpoint source pollutants in rivers, streams, and lakes. Surface runoff is also called overland flow.

Surface Water

All water naturally open to the atmosphere (rivers, lakes, reservoirs, streams, impoundments, seas, estuaries, etc.) and all springs, wells, or other collectors that are directly influenced by surface water.

Suspended Sediments

Fine material (usually sand size or smaller) that remains suspended by turbulence in the water column until deposited in areas of weaker current. These sediments cause turbidity and, when deposited, reduce living space within streambed gravels and can cover fish eggs or alevins.

Taxon	Any formal taxonomic unit or category of organisms (e.g., species, genus, family, order). The plural of taxon is taxa (Armantrout 1998).
Tertiary	An interval of geologic time lasting from 66.4 to 1.6 million years ago. It constitutes the first of two periods of the Cenozoic Era, the second being the Quaternary. The Tertiary has five subdivisions, which from oldest to youngest are the Paleocene, Eocene, Oligocene, Miocene, and Pliocene epochs.
Thalweg	The center of a stream's current, where most of the water flows.
Threatened Species	Species, determined by the U.S. Fish and Wildlife Service, which are likely to become endangered within the foreseeable future throughout all or a significant portion of their range.
Total Maximum Daily Load (TMDL)	A TMDL is a water body's load capacity after it has been allocated among pollutant sources. It can be expressed on a time basis other than daily if appropriate. Sediment loads, for example, are often calculated on an annual bases. A TMDL is equal to the load capacity, such that load capacity = margin of safety + natural background + load allocation + wasteload allocation = TMDL. In common usage, a TMDL also refers to the written document that contains the statement of loads and supporting analyses, often incorporating TMDLs for several water bodies and/or pollutants within a given watershed.
Total Dissolved Solids	Dry weight of all material in solution in a water sample as determined by evaporating and drying filtrate.
Total Suspended Solids (TSS)	The dry weight of material retained on a filter after filtration. Filter pore size and drying temperature can vary. American Public Health Association Standard Methods (Franson et al. 1998) call for using a filter of 2.0 microns or smaller; a 0.45 micron filter is also often used. This method calls for drying at a temperature of 103-105 °C.
Toxic Pollutants	Materials that cause death, disease, or birth defects in organisms that ingest or absorb them. The quantities and exposures necessary to cause these effects can vary widely.

Tributary

A stream feeding into a larger stream or lake.

Trophic State

The level of growth or productivity of a lake as measured by phosphorus content, chlorophyll *a* concentrations, amount (biomass) of aquatic vegetation, algal abundance, and water clarity.

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Turbidity

A measure of the extent to which light passing through water is scattered by fine suspended materials. The effect of turbidity depends on the size of the particles (the finer the particles, the greater the effect per unit weight) and the color of the particles.

Vadose Zone

The unsaturated region from the soil surface to the ground water table.

Wasteload Allocation (WLA)

The portion of receiving water's loading capacity that is allocated to one of its existing or future point sources of pollution. Wasteload allocations specify how much pollutant each point source may release to a water body.

Water Body

A stream, river, lake, estuary, coastline, or other water feature, or portion thereof.

Water Column

Water between the interface with the air at the surface and the interface with the sediment layer at the bottom. The idea derives from a vertical series of measurements (oxygen, temperature, phosphorus) used to characterize water.

Water Pollution

Any alteration of the physical, thermal, chemical, biological, or radioactive properties of any waters of the state, or the discharge of any pollutant into the waters of the state, which will or is likely to create a nuisance or to render such waters harmful, detrimental, or injurious to public health, safety, or welfare; to fish and wildlife; or to domestic, commercial, industrial, recreational, aesthetic, or other beneficial uses.

Water Quality

A term used to describe the biological, chemical, and physical characteristics of water with respect to its suitability for a beneficial use.

Water Quality Criteria

Levels of water quality expected to render a body of water suitable for its designated uses. Criteria are based on specific levels of pollutants that would make the water harmful if used for drinking, swimming, farming, or industrial processes.

Water Quality Limited

A label that describes water bodies for which one or more water quality criterion is not met or beneficial uses are not fully supported. Water quality limited segments may or may not be on a §303(d) list.

Water Quality Limited Segment (WQLS)

Any segment placed on a state's §303(d) list for failure to meet applicable water quality standards, and/or is not expected to meet applicable water quality standards in the period prior to the next list. These segments are also referred to as "§303(d) listed."

Water Quality Management Plan

A state or area-wide waste treatment management plan developed and updated in accordance with the provisions of the Clean Water Act.

Water Quality Modeling

The prediction of the response of some characteristics of lake or stream water based on mathematical relations of input variables such as climate, stream flow, and inflow water quality.

Water Quality Standards

State-adopted and U.S. Environmental Protection Agency-approved ambient standards for water bodies. The standards prescribe the use of the water body and establish the water quality criteria that must be met to protect designated uses.

Water Table

The upper surface of ground water; below this point, the soil is saturated with water.

Watershed

1) All the land which contributes runoff to a common point in a drainage network, or to a lake outlet. Watersheds are infinitely nested, and any large watershed is composed of smaller "subwatersheds." 2) The whole geographic region which contributes water to a point of interest in a water body.

Water Body Identification Number (WBID)

A number that uniquely identifies a water body in Idaho and ties in to the Idaho water quality standards and GIS information.

Wetland

An area that is at least some of the time saturated by surface or ground water so as to support with vegetation adapted to saturated soil conditions. Examples include swamps, bogs, fens, and marshes.

Young of the Year

Young fish born the year captured, evidence of spawning activity.

Appendix X. Unit Conversion Chart

Table X-1. Metric - English unit conversions.

	English Units	Metric Units	To Convert	Example
Distance	Miles (mi)	Kilometers (km)	1 mi = 1.61 km 1 km = 0.62 mi	3 mi = 4.83 km 3 km = 1.86 mi
Length	Inches (in) Feet (ft)	Centimeters (cm) Meters (m)	1 in = 2.54 cm 1 cm = 0.39 in 1 ft = 0.30 m 1 m = 3.28 ft	3 in = 7.62 cm 3 cm = 1.18 in 3 ft = 0.91 m 3 m = 9.84 ft
Area	Acres (ac) Square Feet (ft^2) Square Miles (mi^2)	Hectares (ha) Square Meters (m^2) Square Kilometers (km^2)	1 ac = 0.40 ha 1 ha = 2.47 ac 1 ft^2 = 0.09 m^2 1 m^2 = 10.76 ft^2 1 mi^2 = 2.59 km^2 1 km^2 = 0.39 mi^2	3 ac = 1.20 ha 3 ha = 7.41 ac 3 ft^2 = 0.28 m^2 3 m^2 = 32.29 ft^2 3 mi^2 = 7.77 km^2 3 km^2 = 1.16 mi^2
Volume	Gallons (gal) Cubic Feet (ft^3)	Liters (L) Cubic Meters (m^3)	1 gal = 3.78 L 1 L= 0.26 gal 1 ft^3 = 0.03 m^3 1 m^3 = 35.32 ft^3	3 gal = 11.35 L 3 L = 0.79 gal 3 ft^3 = 0.09 m^3 3 m^3 = 105.94 ft^3
Flow Rate	Cubic Feet per Second (cfs)[a]	Cubic Meters per Second (m^3/sec)	1 cfs = 0.03 m^3/sec 1 m^3/sec = 35.31cfs	3 ft^3/sec = 0.09 m^3/sec 3 m^3/sec = 105.94 ft^3/sec
Concentration	Parts per Million (ppm)	Milligrams per Liter (mg/L)	1 ppm = 1 mg/L[b]	3 ppm = 3 mg/L
Weight	Pounds (lbs)	Kilograms (kg)	1 lb = 0.45 kg 1 kg = 2.20 lbs	3 lb = 1.36 kg 3 kg = 6.61 lb
Temperature	Fahrenheit (°F)	Celsius (°C)	°C = 0.55 (F - 32) °F = (C x 1.8) + 32	3 °F = -15.95 °C 3 °C = 37.4 °F

[a] 1 cfs = 0.65 million gallons per day; 1 million gallons per day is equal to 1.55 cfs.

[b] The ratio of 1 ppm = 1 mg/L is approximate and is only accurate for water.

Appendix X. State and Site-Specific Standards and Criteria

Include salmonid spawning information in this appendix

Appendix X. Data Sources

Table X-1. Data sources for Lower Clark Fork River Subbasin Assessment.

Water Body	Data Source	Type of Data	When Collected
All	BURP	Marcroinvertebrate, fish counts and habitat quality	1995-2002
Clark Fork River	Various Reports produced for the Avista Clark Fork Project license proceedings and Settlement Agreement available at: www.avistautilities.com/resources/hydro/clarkfork/	TDG, fisheries, flow, extensive background on hydropower operations and on-going mitigation and fisheries restoration projects	1995-present
Lightning Creek and tributaries	Lightning Creek Watershed Assessment, Phillip Williams and Associates	Road surveys, landslide delivery, GIS coverages, fisheries data, summary of restoration needs	2004
All	Fish and Game Technical Reports	Redd counts, bull trout densities	
All	WAG personal communication	Land use, condition, restoration needs, priorities, fact checking	2005-2006
Clark Fork River and Lightning Creek	USGS	Flows and water quality data	1990s-2002
Clark Fork River	Tri-State Water Quality Council	Trends Analysis Water Quality data	1998-present

Appendix X. Distribution List

This is the list of those to whom you sent (will send) the TMDL.

Appendix X. Public Comments